WORKSHOP PRACTICE

VOLUME IV

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DRILLING AND BORING

BY

FRED HORNER

GRINDING AND GRINDING MACHINES

SLOTTING MACHINES AND SLOTTING

BY

E. PULL, ENG.-LIEUT., R.N.R.,
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MILLING

BY

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JIGS AND TOOLS

TURRET AND AUTOMATIC LATHES

BY

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WORKSHOP PRACTICE

A PRACTICAL WORK FOR THE DRAUGHTSMAN, THE MECHANIC, THE PATTERN MAKER, AND THE FOUNDRYMAN

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VOLUME IV

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PREFACE

VARIOUS machining operations carried out in engineering works and the plant involved are described in this volume. Lathe work, Planing and Shaping are dealt with in an earlier volume. In the present volume the following subjects come in for consideration. Drilling and Boring, Grinding, Slotting, Milling, Turret and Automatic lathes, Jigs and Tools.

In the section on Drilling and Boring, special care has been taken to provide what is in fact a very complete treatment of the subject. Opening with much sound practical advice on the principles of Drilling, the correct method of shaping drills and their proper handling, the section concludes with detailed information of all the best-known modern drilling and boring apparatus, with references to special features of design and operation.

Closely associated with boring is the question of Grinding. An enormous amount of grinding work is nowadays undertaken, especially in connection with automobile work. Grinding affords an ideal way of finishing off work to very exact limits. Concise particulars are given in this section as to the types of and use of the various forms of abrasives and, in fact, all matters relevant to the subject.

Immediately following the section on Grinding is a short section on Slotting Machines, which, owing to their close similarity to shaping machines, do not call for very detailed consideration.

Milling is an operation very widely performed indeed in metal-working shops, and a section of some thirty pages is devoted thereto. All the important points are touched upon.

A lengthy section is one dealing with Jigs and Toc which in these days of mass production and standardiz tion should perforce interest a very large number engineering employees. It is from the pen of an auth of quite exceptional practical experience.

The final section deals with Turret and Automat Lathes.

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SECTION XVI

DRILLING AND BORING

A CONVENIENT distinction between drilling and boring is that the one takes place in solid metal, the other implies enlargement of a hole already existing. There are, however, deviations from this general statement, as some holes are enlarged by drills, and some boring is effected by tools that originate through solid metal. The reasons for the choice of one practice or another are usually economic ones. It is generally cheaper to cast or punch a hole above a certain size, rather than use power in removing the whole of the material in a machine. Yet sometimes it is just as quick to bore or trepan, and occasionally sounder metal is ensured thereby. A great distinction occurs between general manufacturing and specialization. For the first named, it may not pay to core or forge certain openings, as they can be drilled rapidly at less cost. But repetition work may be machine moulded or drop forged, and the holes produced with great accuracy and closeness to dimensions, leaving only a trifle for the opening-out tools to remove. These tools are thus enabled to operate at fast rates, since they are not subjected to varying stresses due to very thick and very thin parts, and the accuracy of finishing is materially assisted, holes being made round and parallel with the least wear on the tools. In the case of thin parts, such as cylinders and liners, circular truth is not easy to obtain unless the cutting conditions are facilitated thus, because there is a tendency to push the metal away at the thick lumpy portions in bad castings.

The processes of drilling and boring can be accomplished in many ways—by hand power, in the drilling machine, the boring machine, the ordinary lathe, the engine lathe, the vertical lathe or turning mill, the turret lathe and automatic screw machine, with portable machines, and in specialized designs for single or multiple action. The speeds vary immensely, for one of the finest class of drills for tiny holes will run at 20,000 revs. per min., while a boring machine of the biggest class will take about two minutes per revolution of the head. Drilling or boring frequently constitutes part only of the work performed on a given machine. Accuracy is assisted as well as time saved by doing other operations, either simultaneously or successively, without disturbing the setting of the work, the most striking results in this direction being those obtained on the turret lathes.

TOOLS FOR SMALL AND LARGE HOLES

The variations in the choice of drilling and boring tools are very great, being determined sometimes by the material worked on, and by the relative size of a hole, or the quality of finish or accuracy required. The question of the manner of finishing affects the selection of the drilling or boring tool in some instances. Also the truth of starting, as when a piece is done in the lathe or the turret lathe, may determine the selection of certain tools for first, and second processes. If a hole has simply to be made without needing any special accuracy, it is put through at the fastest possible rate, probably in quite a different way from another demanding the finest accuracy as to concentricity, circular and longitudinal truth, and finish of surface.

Although the old-fashioned flat drill is still used extensively by small workers, such as watch- and clock-makers, scientific instrument makers and amateurs, it

has been largely superseded in engineering factories. The chief examples still retained are those of special drills, with angles and sizes not available in standard list drills, while in brass work, especially, they are extensively utilized, not so much to put plain holes through as for those of stepped kind, or parallel and

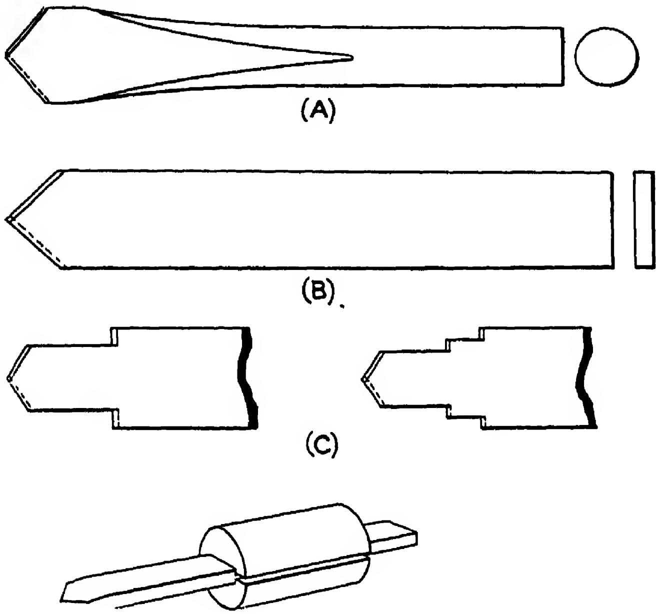


FIG. 1. EXAMPLES OF FLAT DRILLS, AND PAD TO ENABLE *B* AND *C* TO BE HELD IN A TURRET OR CHUCK

tapered in succession, the drill being suitably formed along its edges. A certain kind of drilling or opening-out of cored holes is also done in the lathe with flat bits, which stand the destructive action of the sand and scale well, and can be cheaply sharpened or remade. Finally, the ratchet drill and, sometimes, the pneumatic and electric portable machines, use flat drills for heavy rough service in boiler and bridge work.

The difference between the ordinary flat drill and

the kind for brass work on the turret lathe is that the first is forged from a cylindrical shank, Fig. 1 *A*, for convenience of holding in a chuck, or for squaring the end for a brace, while the second is ground up from flat steel, *B* and *C*, and is gripped in a slotted pad, as shown, secured in a hole in the turret or other feeding device. The drill is only allowed to project from the pad to the distance necessary for reaching into the work. All these flat drills are merely scraping tools, that is, they possess no front rake, such as is really necessary for good drilling in cast and wrought iron and steel. An attempt can be made in this direction by twisting each lip slightly forward, so that it has front rake, or by grinding a hollow at the front; but these methods do not endure for many sharpenings, hence the tools cannot compete successfully with the twist drills. the spiral of which affords front rake no matter how many times the lips are sharpened. Another objection to any kind of flat drill is that the cuttings have no incentive to emerge from the hole, but tend to pack more or less tightly, a matter of little moment only in shallow holes. Yet the twist drill, which screws the chips out so well when rotating, does not show to much advantage when used in a stationary attitude, i.e. as held in a turret while the work revolves. Consequently, while big twist drills are necessary with ordinary drilling machines, their considerable cost is not warranted for turret lathe employment, and large holes are put through by some other kind of tool, such as a fluted drill with an inserted point of high speed steel, or a

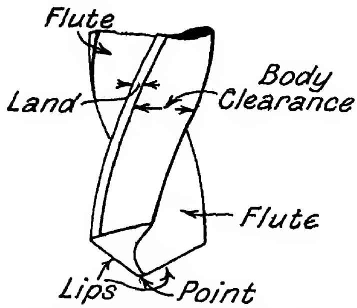


FIG. 2. THE WORKING ELEMENTS OF A TWIST DRILL

preliminary hole is made with a smaller twist drill, to be enlarged by a boring bar, with cutter that only costs a trifle.

TWIST DRILLS

The elements of a twist drill comprise the body (Fig. 2), the flutes, the lips or cutting edges, the point (which does not cut), the land or portion of full diameter which guides the drill in the hole, and the body clearance or relief. In a perfectly-ground drill the point lies exactly central with the axis of the body, and the lips are of equal length and angle. Such a tool will work at the highest possible capacity, and make a round, smooth and parallel hole of the same diameter as the rated size of the drill. An obvious indication of this state is to put the drill into a bit of soft steel, and if the chips curl out exactly alike (Fig. 3), the matter is sure. But if one spiral is smaller in diameter than the other, or broken up, the lips are not each doing their proper half share.

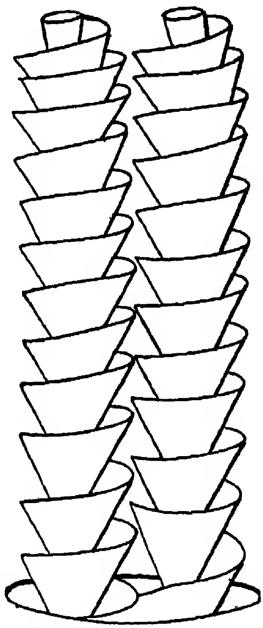


FIG. 3. EQUAL CUTTINGS, WHICH SHOW THAT A TWIST DRILL HAS BEEN GROUND PROPERLY

Two of the principal faults in sharpening are revealed by Fig. 4. At *A* the point is out of centre, or in other words, the lips are of unequal lengths. Such a drill will make the hole oversize, because the diameter will equal the double radius cut by the longer lip.

At *B* the point is central, but the lips are ground at different angles. Here most of the work will fall on the one lip, and oversize drilling will also result. The worst fault is to have the angle of lips different, and

of different length ; this throws great strain on the machine and the drill. Fast production is impossible under any of the foregoing conditions, apart from the faulty holes and the wear and tendency to breakage of the tools.

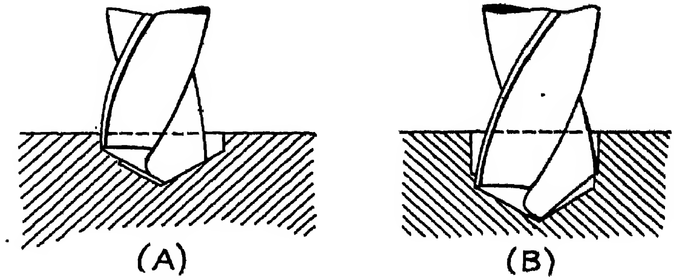


FIG. 4. FAULTY GRINDING OF TWIST DRILL LIPS
A = Point out of centre *B* = Lips at different angles

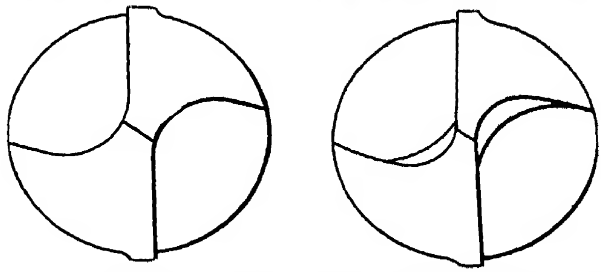


FIG. 5. THICK POINT WHICH MAKES PENETRATION DIFFICULT, AND THE DIFFERENCE AFTER THINNING

For reasons of strength, the web of a drill gradually becomes thicker towards the shank. This has the disadvantage of thickening the point as the drill shortens, so that it grinds on the bottom of the hole and adds to the labour of drilling, and produces extra heat. With a suitable oilstone or a narrow grinding wheel the point can be thinned (Fig. 5) for a reasonable distance up. Of course, the operation must not be carried to excess, or the web is liable to split when pressure is applied.

Twist drills are best sharpened by machine, which gives accurate angles, equal lengths of lips and central point, but with some practice the smaller drills can be ground up very truly, testing with a gauge. It is difficult to describe hand sharpening, but the drill is held

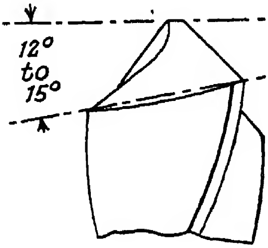


FIG. 6. THE CORRECT ANGLE OF CLEARANCE BEHIND A DRILL LIP

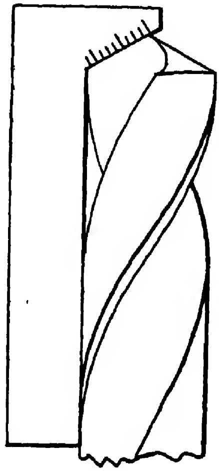


FIG. 7. GRINDING GAUGE TO TEST DRILL FOR ANGLE AND LENGTH OF LIPS

with the left hand near the point, while the right hand grips at the extreme end of the shank. As the lip is thus held against the wheel, the right hand is given a slow downward movement simultaneously with a motion to the left, resulting in a clearance curve as drawn in Fig. 6. This clearance is as it exists at the largest diameter of the drill, but must be gradually increased towards the centre. Insufficient lip clearance prevents the drill from cutting effectively, and it is likely to split up the centre, while excessive clearance weakens the cutting edges and they are liable to fracture. A simple gauge to test the angle of lips (best at 59 degrees) is of sheet metal (Fig. 7), and it also

reveals whether each lip is uniform in length, by reference to the graduations.

The ordinary two-lipped drill, hitherto considered, cannot properly be employed for redrilling, that is the enlargement of holes, because of the lack of support for the point, and bad working and breakage are inevitable. Three-flute and four-flute twist drills are, however, made for enlarging and truing drilled, punched or

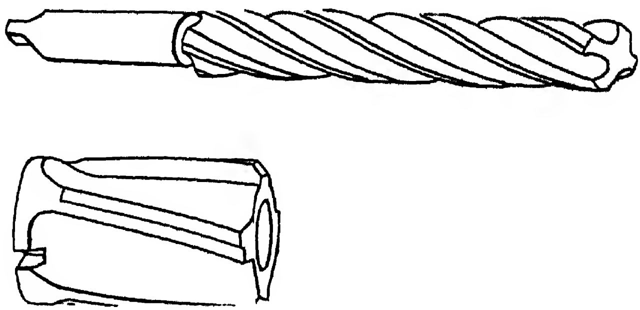


Fig. 8. Four-fluted Twist Drill for Enlarging Holes, and Shell Drill, held on an Arbor

cored holes. The points are not suited for originating holes, but the guidance on the lips is such that a perfectly steady action is obtained, and the holes turn out truly circular and straight. Fig. 8 gives examples of these tools, including the shell type, which fits on a long arbor. They are much in demand on the turret or "chucking" lathes, which drill, bore, face and turn wheels, pulleys, flanges, covers, etc.

For most requirements twist drills are made to cut right-handed to suit the direction of rotation of the majority of machine and lathe spindles, but left-hand drills are occasionally required to use in automatic screw machines and in double-ended spindle drilling machines, at one end of which a left-hand drill must attack. There are a good many different types of drills, as regards the length of body, and the class of shank to

suit particular chucks. or holders. The temper is also varied in certain instances to suit particular requirements, a case in point being boiler-plate drills, which are tempered to resist the severe shocks from drilling springy plate. Extremely short drills are supplied for specific functions, as for use in ratchet braces or portable power machines in confined heights, and also for starting holes in turret lathes, to get a true beginning for the

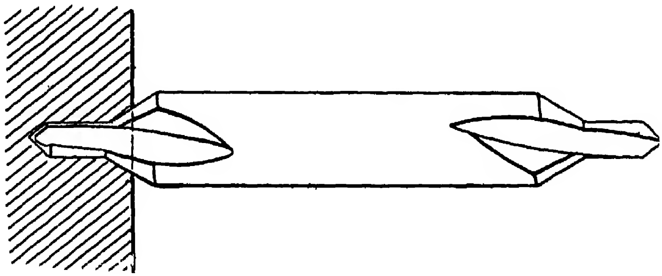


FIG. 9. COMBINATION DRILL WHICH MAKES CENTRE HOLE AND COUNTERSINK AT ONE OPERATION

long regular drill. Centre drills are of small diameter, and prepare centre recesses in work to mount on the lathe or grinder centres, a separate countersink being used to make the cone shape. The quickest and best tool, which ensures absolute concentricity of these holes, is the Slocomb type, or combination centre drill (Fig. 9).

STRAIGHT FLUTE DRILLS

The twist drill cuts with rather too much avidity in brass and related soft materials, so that it pulls through the back of the metal suddenly. This would not matter so much if the work were rigid and non-springy, likewise the table, and the spindle feed apparatus in perfect order, but at the same time there is really no need to use the twist type because top rake is not necessary for the material in question. Consequently, a straight flute drill (Fig. 10) is the proper tool to select, its only

disadvantage being that the chips pack in the flutes more than they do in a spiral flute; although if the drill is held non-rotatively (as in a turret) the escape of cuttings is as good as with a spiral flute. There is a straight flute drill for steel used in the turret lathe, which has an inserted point ground with the proper spiral to give front rake.

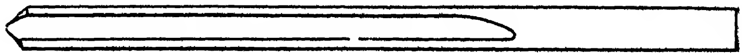


FIG. 10. STRAIGHT FLUTE DRILL, WHICH IS PREFERABLE TO A TWIST DRILL FOR BRASS

DRILLING PRACTICE

Before dealing with the various boring tools, some idea may be given of the methods of using the twist and other drills. The start is important in a great many instances, because a hole must usually be placed in a fairly exact position. If a drilling jig is employed, the bushings incorporated in its construction act as guides, and there is nothing to worry about. But in ordinary operations an impression has to be made with a centre punch, and a circle struck about equal in diameter to the size of the drill. The latter is fed down on the work, which is held or clamped with the centre pop exactly in the machine axis. If the machine and drill are in good condition, and the point of the latter is not too thick, the start will be well made. Should the impression, however, come out of centre, the drill must be stopped, and a centre punch—or a chisel for the larger holes—be applied to create a cavity (shown in black in Fig. 11), into which the point will slip on the next application, and so draw the drill to a concentric position. Sometimes it is best to use a short stiff drill, or a combination centre drill, which will work accurately

to the centre pop. The start of a hole drilled in the engine lathe or turret lathe is usually made with some sort of short stiff tool, so as to avoid any necessity for this kind of correction. A pointed tool can be held in the slide rest, a centre drill in the poppet or in the turret. In the last instance, a couple of facing blades

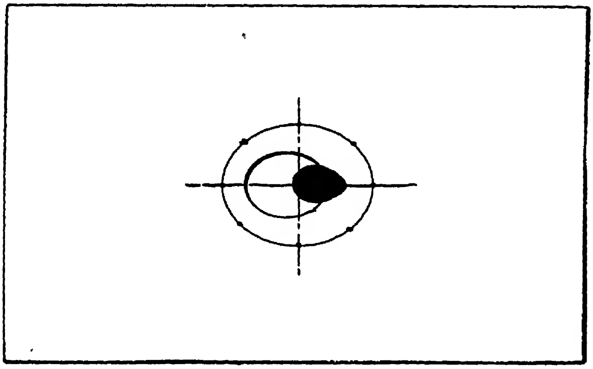


FIG. 11. METHOD OF "DRAWING" OVER A START MADE OUT OF CENTRE, SO AS TO LEAD THE DRILL POINT CENTRALLY

are often held in the holder to true off the end of the piece.

To do the best work, the holding appliances of drills must be in proper condition ; the shanks must not be torn up or bent, nor the sockets damaged or burred. Inefficient support of the work, or play in the feed mechanism are also to be avoided, because as the lips emerge at the back of the piece the release of the pressure causes them to catch in and possibly break. Careful feeding at the last bit is therefore a thing to be noted. There are several causes of drills breaking, one simple instance being that of penetrating too deeply, so that the flutes are covered and become choked with chips, making the tool bind hard. If the lip

clearance is too great the edges are liable to chip out, as they will also if the feed is too heavy. When it is found that the corners of the lips wear unduly, this reveals too high a speed.

LUBRICATION

It is not necessary to apply any lubricant when drilling brass, nor for cast iron; but the fibrous materials, including malleable cast iron, and the steels

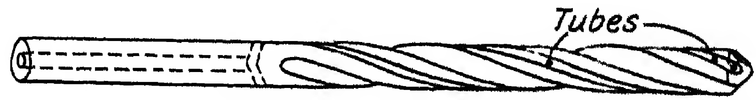


FIG. 12. DRILL WITH CENTRAL PASSAGE AND HOLES CONNECTING TO TUBES SUNK IN THE LANDS, TO FORCE OIL TO THE CUTTING LIPS

will tear up and make the drill hot in a few seconds. Soapy water, oil, or one of the compounds diluted with water are employed; turpentine is good for hard steel. The stream of lubricant, supplied in small operations from a drip-can, and with a pump for continuous regular manufacturing, must be sufficient in volume thoroughly to flood the drill. Some of the drilling jigs, using several drills simultaneously, have a top plate cast with a rim around so as to act as a container for a flood of compound, which thus reaches each drill in ample volume, the pump working all the time.

Positive conduction of the fluid to the lips may have to be ensured in certain examples, as those of deep holes drilled in the usual vertical position. The choking of the flutes with cuttings has the effect of interfering with access of the oil to the point; and in horizontal drilling, done in the turret lathe, and special types of drilling machines, gravity does not help. To meet these difficulties, the oil-tube drills are manufactured (Fig. 12) with copper or steel tubes fastened into grooves on the

lands, and connecting to a central hole in the shank. The supply being pumped through, this reaches the bottom of the hole and rushes out, conveying away the heat and cuttings. If the drill is employed in a revolving spindle, the oil is conveyed to a fixed collar encircling the shank at the top of the flutes, and an annular groove thereon leads to cross-holes communicating with the central hole and thus to the tubes. Alternatively, drills are available with the oil holes drilled in the solid metal of the lands.

SPEEDS AND FEEDS

With the exception of abnormal materials, such as very hard steel, or a piece of cast iron which has been chilled or has hard spots, the rates of speed and feed are well established for various metals and alloys and using ordinary carbon, and high speed drills.

Diameter of Drill	Revolutions per Minute		
In.	Brass	Cast Iron	Mild Steel
$\frac{1}{8}$	3660	2290	1980
$\frac{3}{16}$	2440	1520	1320
$\frac{1}{4}$	1830	1140	990
$\frac{5}{16}$	1460	910	790
$\frac{3}{8}$	1220	760	660
$\frac{7}{16}$	1040	650	560
$\frac{1}{2}$	910	570	490
$\frac{5}{8}$	730	450	390
$\frac{3}{4}$	610	380	330
$\frac{7}{8}$	520	320	280
1	450	280	240
$1\frac{1}{4}$	360	220	190
$1\frac{1}{2}$	300	190	160
2	220	140	124
$2\frac{1}{2}$	180	110	100
3	150	90	80

Exact numbers of revolutions per minute are calculated to give the suitable rates of peripheral speed of the drills, which are, for high speed drills, 120 ft. per min. in brass, 75 ft. per min. for cast iron, and 65 ft. per min. for mild steel. Extra hard cast iron and tool steel must be done at a suitably slower rate. Omitting odd figures between the tens, the speeds may be quoted as shown on page 831.

Feed rates vary so widely, according to the class of material and the work done, that no specific examples can be conveniently given, although in manufacturing on a large scale, with metals of uniform character, they are tabulated for the purpose of setting the machines. As a rough guide, however, it may be mentioned that in mild steel and soft cast iron a ¼ in. drill can be fed at the rate of 10 in. per min., a 1 in. at the rate of 4 in. per min., a 2 in. at 2¼ in. per min., and a 3 in. at 1½ in. per min. Yet these rates are easily exceeded with drills and machines maintained in the best condition, and still more so for test and demonstration purposes. For instance, a ½ in. drill may be made to feed at the rate of 30 in. a minute in cast iron.

BORING TOOLS AND BARS

The actual difference in principle between a drill and a boring tool is that the one has a penetrative point, the other can only enlarge a hole. This distinction is subject to slight modification in certain practice, but for 90 per cent of work it holds good. Boring tools are divisible into rotating and non-rotating types. The first are run in drilling and boring machines, the ordinary lathe, occasionally in milling machines. The second in the ordinary lathe, the vertical lathe or turning mill, and to an immense extent in the capstan and turret lathes, both semi- and full-automatic. Generally, the reason for the use of one or the other type is that

of how the work can be held. When it is of such shape that rotation is inconvenient or impracticable (e.g. an awkwardly-shaped cylinder or bed or frame casting), the revolving bar or head has the preference. But if the work is of what may be termed the lathe class, that is, it can be held in a chuck or on a face plate, or mounted in a fixture for repetition work, the tool or bar need only be fed up and into the hole. The most elaborate equipments occur in the turret lathes, starting tools, drills, boring and facing bars, reamers, recessing tools, counterboring, and other cutters being extensively included. Some work is done out of the solid, being drilled, then bored, and reamed, and further treated according to the drawings ; or castings or forgings with rough holes in are bored directly. In the engine or ordinary lathe a great amount of boring is performed with bent tools fed up from the slide rest, and the cylindrical bars holding cutters are not so often employed. But, as in the horizontal turret lathes, bars are utilized freely in the vertical lathes, which machines often possess a turret.

The rotating-bar method of boring originated in the lathe, being run between the centres, while the object was clamped on the saddle and fed along. This practice still obtains in amateur and garage and general work, but, otherwise, the regular boring machines are more convenient as regards setting and adjusting the work and manipulating the bar. In large machines the work does not feed, but the bar is traversed, or the bar merely rotates, and a cutter head fitted with a key and spline feeds along the bar by a screw action.

The simplest cutter, whether for a rotating or non-rotating bar, is either of rectangular or of cylindrical shape. The former type used to be favoured most, but the simplicity of just drilling a cross-hole and grinding a cutting edge on a length of standard tool steel is so

attractive that great numbers of bars for small and moderate-sized holes are thus made up. The principal exception is found where it becomes essential to provide a longer edge than that afforded by the cylindrical cutter; this requirement, for instance, occurs when the bottom of a hole has to be faced simultaneously with the conclusion of the boring operation, or where the latter is of a special curved or other shape, needing perhaps an inch or two or three inches of edge to grind to contour. Heavy cuts in the larger sizes of holes must also be taken with a thick flat cutter, able to endure the severe pressure, and to withstand repeated sharpenings. There are very many scores of different designs of bars, with various ways of securing and adjusting the round or flat-section cutters, as well as heads on bars, but it is only possible here to illustrate a typical selection. The important feature in any style of fastening is rigidity, so that the cutter shall neither slip back from the cut, nor tremble so much as to spoil the surface. Some cutters are just held frictionally by the screw or wedge fastening employed, others are positively locked by a shoulder touching the bar, or by a screw exerting end pressure, this also acting as an adjusting agent. In some degree the class of hole bored affects the method of fastening the cutter; thus, if it is a blind hole, or there is an obstruction just beyond

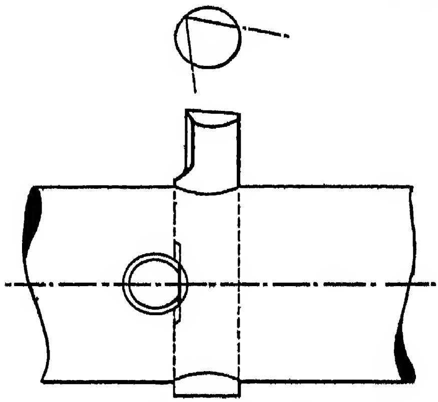


FIG. 13. BACK AND END VIEW OF SIMPLE BORING CUTTER GROUND UP FROM ROUND STEEL, AND HELD BY WEDGE PIN OF ROUND STEEL

the back in the shape of a face plate, chuck, or fixture, it is not possible to use an end screw, unless of the grub or sunk variety. On the other hand, should the cutter be only slightly larger in radius than the bar exterior, any kind of projecting screw or wedge becomes impracticable.

The grinding of the round-section cutter is depicted

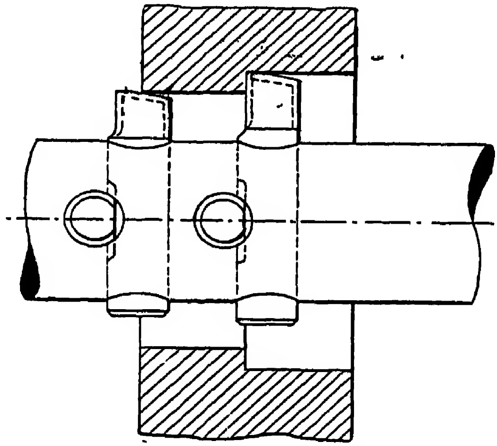


FIG. 14. BORING TWO DIAMETERS, OPERATION JUST COMPLETED

in Fig. 13, to give front and top rake, and side clearance. This shape is suitable alike for the smaller bars of rotating or non-rotating class. If a hole with two diameters has to be bored, two cutters can be fitted after the manner of Fig. 14, as an alternative to a flat cutter with the edge shouldered suitably. The single-ended forms shown have the advantage that they may be adjusted to cut a certain range of diameters, but for repeat boring, or to finish a roughed-out hole nicely to size, a double-ended cutter is advantageous, being locked centrally in the way shown (Fig. 15). A wedge applied at the back face of a cutter is common practice for the flat ones, as represented in this

specimen. Set-screws are excellent for fastening, if there is space for the square head; if not, then the hollow kind of screw may be fitted, with a square or hexagon recess to take a key. As mentioned, if there is no end obstruction, a screw can be located in the end of a bar (Fig. 16), of the type used in boring machines and turret lathes, that is with this end free to travel

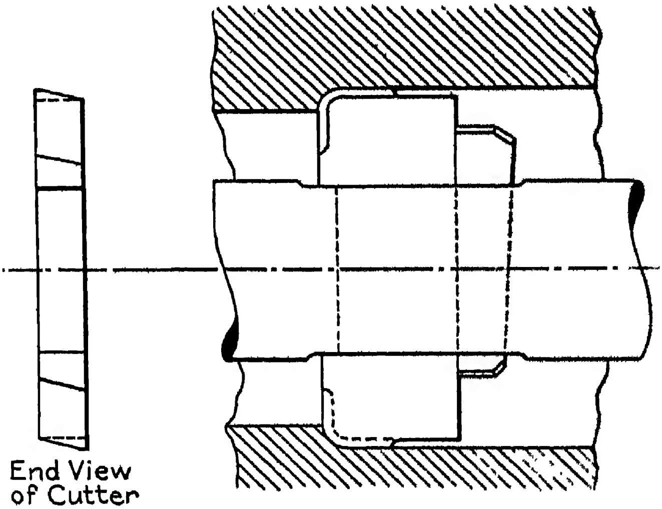
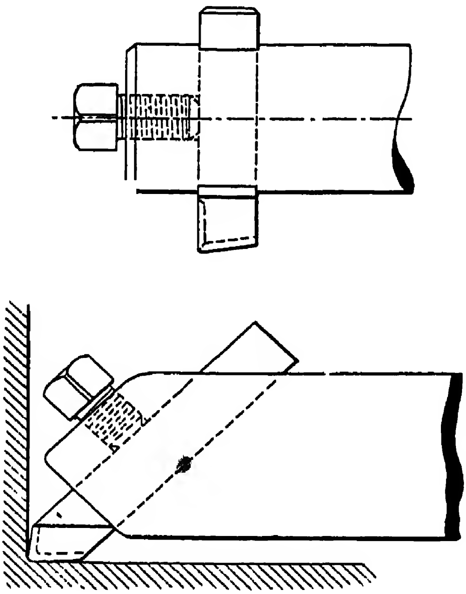


FIG. 15. FLAT DOUBLE-ENDED CUTTER CENTRED BY ITS NOTCH, AND LOCKED WITH WEDGE

in space, or into a pilot hole which acts as a centralizing guide. A popular design to utilize in the vertical lathes (turning mills) has the screw set at an angle, and the cutter also inclined so that it will reach into a corner (see Fig. 17). Often a second screw is tightened on the top of the cutter for extra security, or the cutter hole is not carried full size right through the bar, a section being reserved at the tail end, and tapped for an end stop-screw. Another mode of reaching to the bottom of a hole is that of milling a slot across the end of a bar to receive a cutter of square section steel,

making a saw cut some little distance back from this, and passing a transverse screw through the bar, so that its contractile action causes the split end to grip the cutter immovably. Sometimes also the cutter is a flat one, with a longitudinal split partly up it, and a supplementary screw with conical point presses into



FIGS. 16 AND 17. SQUARE-SECTION CUTTER MOUNTING
Above, cutter fastened by end screw
Below, cutter fixed for boring to blank end

the split so as to spread the steel very slightly, just sufficient to modify the cutting size, before the binding screw is tightened. Expansion cutters are also made in halves to fit anywhere along a bar, according to where it is most desirable to have the receiving slot. A wedge arrangement effects the tightening, the cutter halves being first spread apart to the exact cutting diameter desired by means of a pointed screw with a micrometer head reading to the thousandth's of an inch difference.

BORING HEADS

A head becomes necessary in two circumstances—(1) if the diameter of the bar and that of the bored hole are so much different that the cutter would have excessive overhang; (2) when it is required to alter the position of the cutter or cutters along the bar, a

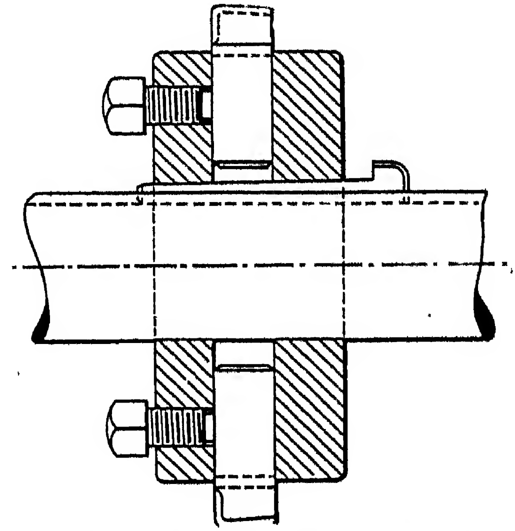


FIG. 18. SIMPLE HEAD WITH SQUARE-SECTION CUTTERS

frequent demand in turret lathe operations. As with cutters fitted direct, there are scores of variations in the designs of heads, some receiving one cutter, some three, four, or six. In theory, the greater the number of cutters the faster the feed rate may be, but this does not work out in actual construction and practice. In fact, some of the biggest work, that of boring turbine casings, is performed with a double-arm or spider head carrying an adjustable tool slide at each end.

The set-screw binding method is much favoured, such as in Fig. 18, for either two or three square-section cutters. On the Pearn-Richards horizontal boring,

facing, drilling and milling machines, a special disposition of cutter is employed for the heads ; they are made as in Fig. 19, so that the shanks point away from the direction of rotation, the ends being forged with a hook to bring the angle of rake correct. The effect of this backward slope is to give what is termed a trailing cut,

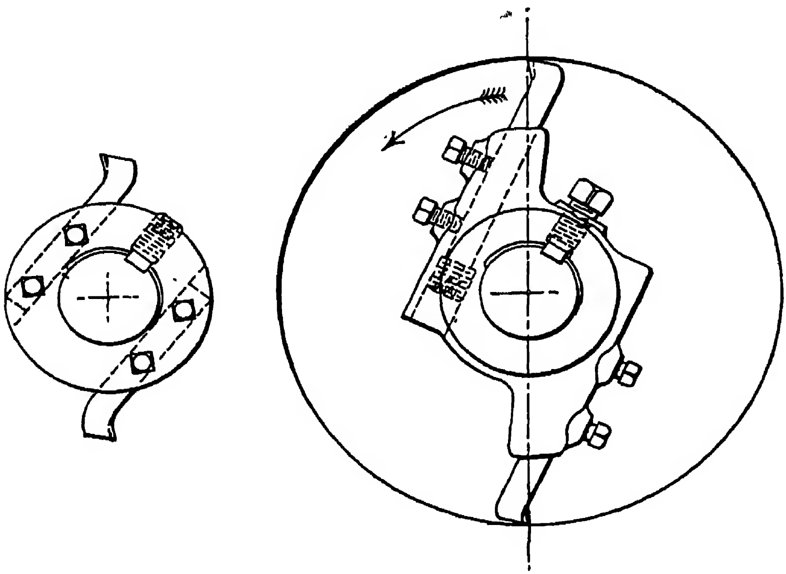


FIG. 19. PEARN-RICHARDS BORING HEADS DESIGNED TO GIVE SMOOTH CUTTING

that is, the cutter does not tend to dig in deeper if it springs, but rather to fall away from the metal, and the result is reduction of vibratory and jerky action, and a smoother finish. The smaller type heads bore up to a maximum of 12 in. diameter, the larger to 25 in., these latter having end-adjusting and stop-screws behind the tools. The fit on the bar is half-relieved, so enabling the head to be slid easily to any position, and on tightening the screw on to the key the half bore makes a perfect fit with the bar. Other methods of

clamping the cutters in various heads include flat plates pulled down by two screws, the tool lying in an open groove; and a bolt with a large slotted head, through which the tool passes and is thus pulled down into a groove. Both of these devices hold very powerfully.

FACING

This operation may be done in two principal ways, either by a cutter or two cutters having sufficient length of edge to clean over the whole surface when fed against it; or by a star-feed apparatus, which traverses a tool slide bit by bit along an arm as the bar revolves without end-long motion.

An area of large diameter or one of considerable width cannot be tooled off with the cutter method, because penetration is so difficult and chatter excessive. If it is necessary to face off a casting or forging with anything but a small annular surface, the cutter is made with a wavy or corrugated edge, which bites into the scale more easily than a plain edge. Usually, then, a second or finishing cutter has to be used to give a smooth true face, but squared notches may be staggered on opposite sides of the cutter, so that the net result is to leave a flat surface. There is a vast amount of facing performed in the turret lathes, because drilling and boring are done at the same setting which finishes off the exposed face of a casting or forging, or a piece turned out of solid bar. Frequently, the boring bar also carries the facing cutter, which comes into play at the last moment, or a separate bar acts as a pilot into the work or the spindle bush, and holds a head with one or two facing cutters. Fig. 20 illustrates the fast type, and Fig. 21 the second, one of the cutters being for forming the recess, this being really a species of facing. Large heads for dealing with pulleys, wheels, gear blanks, covers, etc., in the

big turret lathes often have three tool-holding devices surrounding the pilot bar. Two take flat cutters to face, form, or recess by, and one is radially adjustable

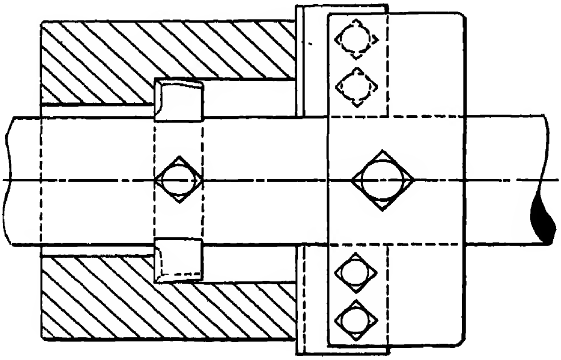


FIG. 20. FACING HEAD FIXED ON BORING BAR

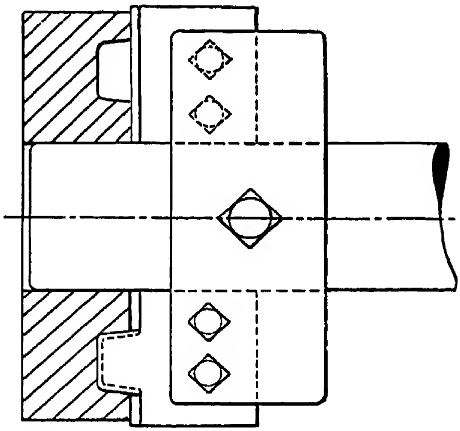


FIG. 21. FACING HEAD ON BAR HAVING PILOT

so that an exterior turning tool may be set to the desired diameter, and the rim of a blank be turned to size at the same feed as the facing cut.

The star-feed apparatus is so called because a star-wheel at the end of the slide screw (Fig. 22) encounters a fixed pin on the machine at each revolution of the

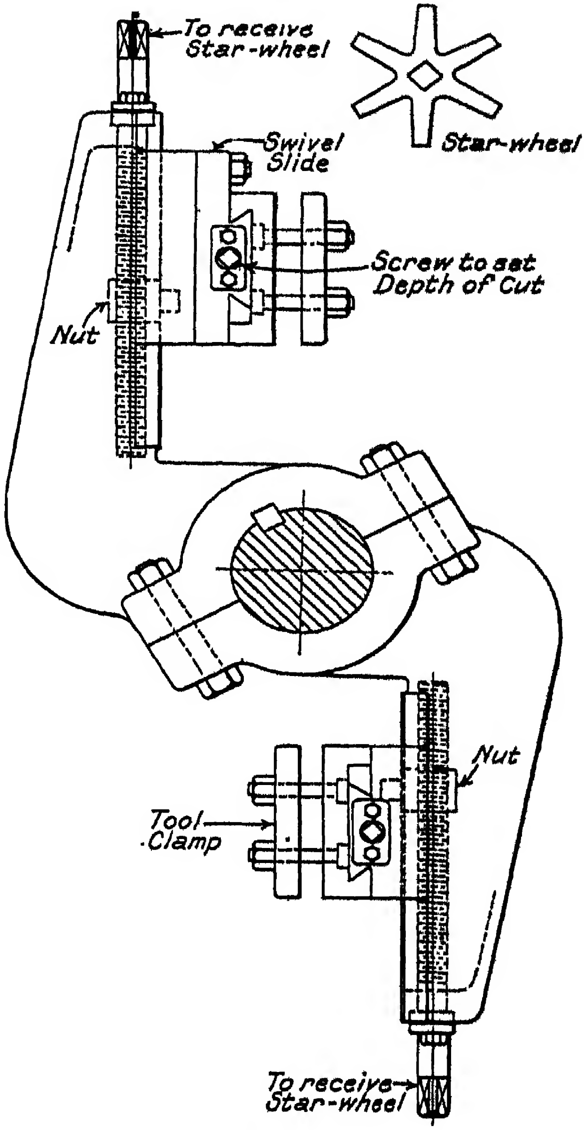


FIG. 22. FACING ATTACHMENT BOLTED ON BORING BAR

At each revolution one of the arms of the star-wheel strikes a fixed pin and receives a partial turn

bar and gives a partial turn to the screw, thus the tool is gradually fed across a flange. In machines of the Pearn-Richards type, which have a rotating head with tool slide for facing, the feed is by a continuous power drive; either inward or outward motion can be instantly obtained. Sometimes this is valuable to rough face a flange on the inward feed, and finish it on the outward.

BORING PRACTICE

The quickest method of boring for all the smaller objects is to revolve them in the lathe, and feed the tool up from the slide rest, or from a turret, or in certain cases from the poppet. The holding is rapidly effected in this manner, and the tool, or tools, may be brought up instantly to rough and finish bore, or counterbore, bell-mouth, face, turn a flange, or make a recess. The chief competitor in this class of operation is the vertical drilling machine, though it does not provide facilities for quick bringing into action of the different tools. For the simpler boring and facing processes, however, it is much favoured.

The normal lathe boring tool is forged from bar similarly to the turning tools, and its end is bent around in order to give proper access, preferably with a forward thrust (Fig. 23, *A*). The finishing tool requires a straight edge, unless a reamer is employed to bring the hole to size and finish. To save steel, bars of the class already illustrated (Figs. 16 and 17) are extensively used; the rectangular shanks are gripped on the slide rest as usual, and the cylindrical ones in a split or divided clamp. The amount of projection of a boring tool should be strictly limited to that actually required for going to the depth, so as to reduce spring and chatter. It is sometimes judicious to hold the tool at first with only a slight degree of overhang, and get the mouth of the hole truly circular and concentric,

after which the extended tool is not so liable to be influenced by the rough hole. Troubles of this sort have to be eliminated in turret practice, otherwise the rate of production would be seriously diminished, and the work would not be finished to the specified limits of error. One scheme is that of having a short stiff tool in the cross-slide, and boring out the mouth of a casting or forging for a short distance sufficient to give a concentric start to the boring bar. To a much

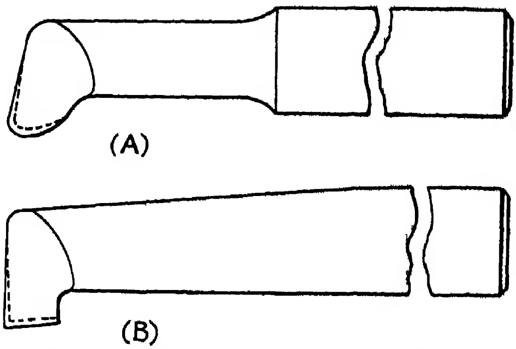


Fig. 23. Standard Boring Tools to Use from the Slide-rest

A. For roughing
B. For finishing, or working up to a square shoulder

greater degree, however, the notion of piloting is adopted ; the bar is projected forward to a length which ensures entry into a steady bush before the cutter begins to operate. The bush may be either fitted n the spindle nose, or into the chuck, the latter being often the better way. The outfit for this style appears in Fig. 24. The other bars in the turret, for facing, counterboring, reaming, etc., should be also similarly piloted for accuracy, though sometimes the reamer is a floating one, as will be seen later. Piloting direct in the bored hole instead of continuing to use the bush is occasionally noticeable, after the hole has been truly bored ; a finish boring tool to smooth and size the bore,

or a counterboring tool is thus guided. Another mode of accurate centralizing is to put a cutter in the end of a bar, to face the bottom of a hole or cut it to a special contour, and have an enlarged diameter on the bar just behind the cutter, this enlargement fitting closely in the bored hole.

Articles that are difficult to chuck and run in balance

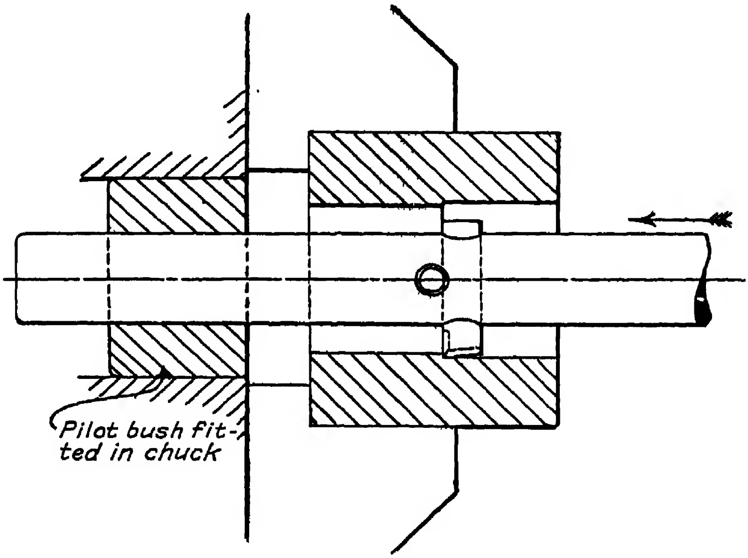


FIG. 24. PRINCIPLE OF PILOTING A BAR IN THE TURRET LATHE

in the lathe (excepting by more or less elaborate clamping, and the setting of balance weights, or the use of a special fixture) are best bolted to a slide, and the bar revolved, while the slide feeds along. This has been a long-established method in the lathe, and is still the only way with amateurs and the small workshops of very limited equipment. The principal disadvantage is that of limitation of height over the saddle, and the necessity for tentative packing and wedging-up to bring the axis of the intended bore in line with the lathe

axis. On regular boring machines there is a good range of height adjustment, either by means of a rising and falling table, or a spindle slide moving up and down a column. Furthermore, instead of mounting the bar between point centres, as in the lathe, it is solidly supported in cylindrical bearings, and there is no trouble from end-long expansion due to heat, which causes a difference in the running of a bar between centres. It should be mentioned that as a certain amount of heat is bound to develop in boring, a finishing cut should never be stopped after once starting through the bore, or a slight ridge will be apparent at the resumption. The natural spring of the bar and the machine and work sometimes has a little to do with this fault.

Other reasons why a bore is unsatisfactory include the use of a bar which is too weak and springy for its duty; inefficient clamping of the cutters, and their wrong grinding or tempering. Excessive rake or clearance causes digging in and chatter, while insufficient forces the cutter away from the metal, and makes it follow the rough bore, more or less, instead of producing a circular and parallel hole. Too hard an edge is liable to chip out and so spoil the cutting diameter, while if too soft there is soon a reduction in size as well as in cutting power. What may be termed nibbling at the work is likewise productive of inaccurate boring, that is not setting the roughing cut sufficiently deep to penetrate to clean metal all along the hole. If the tool scrapes over the low black places instead of going beneath the scale, the edge will be pushed away therefrom and the bar and work will spring. But a good heavy cut, even if taken at a slower rate of feed, burrows under all the scale and is thus unaffected. In a roughing cut it is the corner of the tool which does the cutting, but in a finish cut the length of edge in contact with the bore helps to steady the bar and to impart

a smooth finish. Some heads have steady blocks of hardwood or brass, such as three equally interspaced with three cutters, and these blocks fit the hole and exert an excellent steadying influence. The idea is not perhaps adopted so much as formerly, partly because machines and bars and tools are better made and conditioned, and because so many bores are afterwards sent to be ground on precision machines, if high accuracy and fine finish are desired. Furthermore, it is often better to rough with an outfit minus such steadies, and effect the finishing by means of a reamer, the six or more blades of which afford a perfect steadying action.

The setting of a piece of work to be bored depends on how the hole must be located. Very frequently there is no exact position essential, and the hole simply follows the bore as nearly as possible. The other surfaces of the casting or forging are then machined in relation thereto. Or the piece has to be lined out carefully with scribing block, rule, square, compasses, etc., on the marking-off table, or with the help of a sheet-metal templet, and the bore or bores have to be kept strictly to the circles centre-popped on the whitened end faces. This entails rather more care in some cases, because the circle must be set to run true in the lathe, or adjusted in the boring machine to lie concentric with the bar. In the latter instance a wire pointer can be held in the bar, and the same rotated to test the concentricity, or sometimes a sheet-metal disc is threaded over the bar, and laid against the circle and viewed. It is often the custom to strike a larger, or "witness," line extra to the boring circle. This line affords a witness to whether the hole has been bored exactly true, and if such is not the case, steps may perhaps be taken to alter other machined surfaces by a correction of the lining-out before dealing with these.

Cross-settings are frequently desired, in order to bore two or more parallel holes. Such setting is effected either by a cross-motion of the table slide, or of the spindle head, according to the design of machine. Repetition boring of such a nature is either done with the assistance of a jig, with holes which guide the bar exactly to the required position ; or the cross-slide is set with a spacing device, consisting of a cylindrical bar of length equal to the pitch of the holes, this being laid between stop blocks on slide and table, so acting as a gauge. If only a few articles are to be bored alike, the setting is made by means of a rule or some type of adjustable gauge.

The rotary table is a useful adjunct on which to bolt objects that need boring and facing on opposite sides, or at right or other angles. Its rim is graduated in degrees, and any angular setting may thus be made. Another fitting is the square revolving table, swivelling on a pivot pin. This affords a large area to carry work, and is fully supported upon the main table. Four clamps pressing on ledges hold the fitment down, after the necessary setting has been arranged. Frequently, automatic locking at right angles is arranged by means of a tapered plug pushed into one of the four notches around the base, and then secured with a bolt (Fig. 25). Subjects dealt with by the aid of this quartering attachment include engine and pump cylinders, beds, machine framings, gear-boxes, steam and water valves, and pipe castings with two or more flanges at various positions. On the more complete boring machines it is possible to do drilling, facing, milling, etc., so that a rather complex casting may be fully machined without removing it from the swivelling table. Occasionally, the indexing action is employed to revolve a multiple jig or fixture into the four positions, each face or level area of the same holding an article to be bored and faced. The

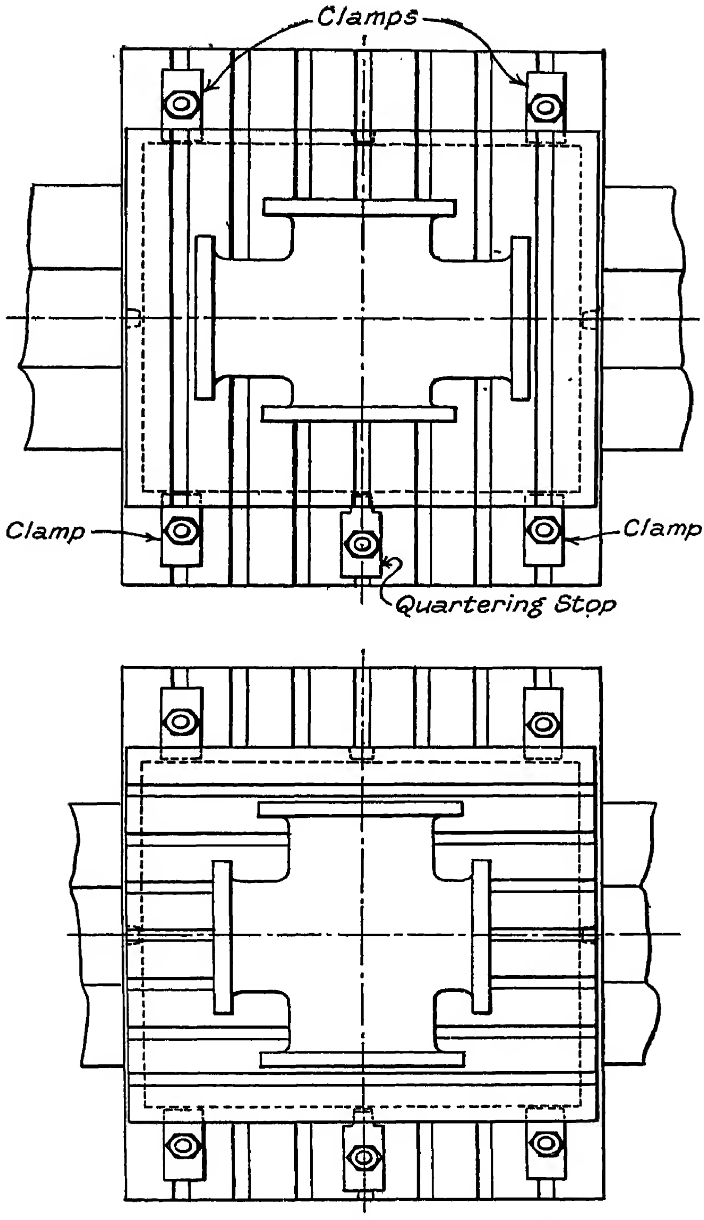


FIG. 25. SQUARE ROTARY TABLE WITH QUARTERING STOP AND CLAMPING PLATES

operator can remove a finished piece, and reload at one of the stations during the boring at another.

The snout boring machine is a useful type which does not use a long bar of the usual class. It has instead a long snout or tubular casting in which the boring spindle runs, and is thus able to penetrate deeply into a hole without loss of rigidity. The design possesses special value for dealing with blank-ended holes, or those with only a small aperture at the end, not big enough to admit the boring bar usually passed through a bore. On the Pearn-Richards combination machines, mentioned previously, a modification of the snout device is utilized for miscellaneous operations not so conveniently performed in the ordinary manner. A telescopic snout is fixed into a socket bolted to the slide of the driving head, which slide possesses the usual radial feed action either outwards or inwards. The tool held in the snout may therefore describe a circle of any desired diameter for simple boring, the axis being central with the machine spindle axis ; or, using the radial feed, a flange may be faced off or an internal face done. The periphery of a flange can also be turned or "edged." These processes are illustrated in Fig. 26.

REAMERS

Some classes of work are done quite well enough if the holes are drilled or bored, either with a moderate finish and accuracy, or a rather good condition in these respects. But the reamer as a finishing and sizing tool is so simple to use that its services are in universal demand for completing holes, even though it would be feasible to treat these with the drill or boring tool alone. The trouble with either tool is that of sizing, which needs careful grinding or setting, and the maintenance of these conditions. It is simpler to rough out and let the reamer take care of the exact size, which it will do

for a long period, owing to the small quantity of metal it has to remove. Its guidance also is excellent, because

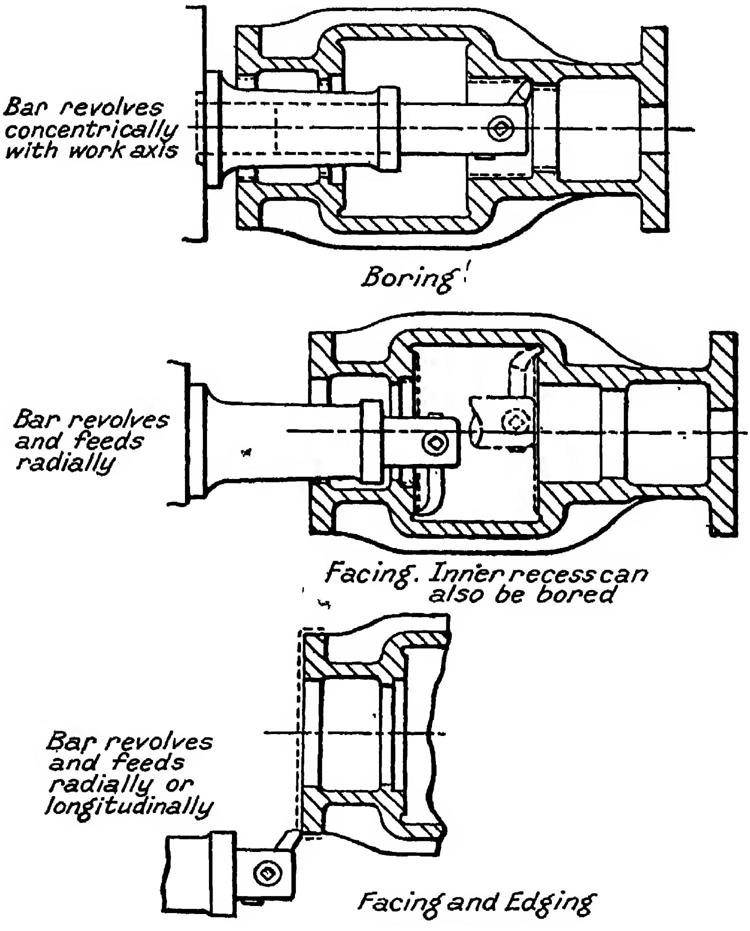


FIG. 26. SOME OF THE OPERATIONS WITH TELESCOPIC SNOUT AND FACING HEAD ON PEARN-RICHARDS MACHINES

of the number of edges bearing in the hole. The half-round reamers do not enter much into engineering practice, though largely utilized for fine instrument making, amateurs' work, and such-like. Their cutting powers

are somewhat indifferent by contrast with the multiple-toothed tools. A simply made reamer, however, and one able to endure hard rough service, particularly with the ratchet brace, can be prepared from bar after the style of Fig. 27 *A*, grinding the end similarly to a flat drill; this cuts well, and the body affords good guidance in the hole. It is sometimes termed a broach,

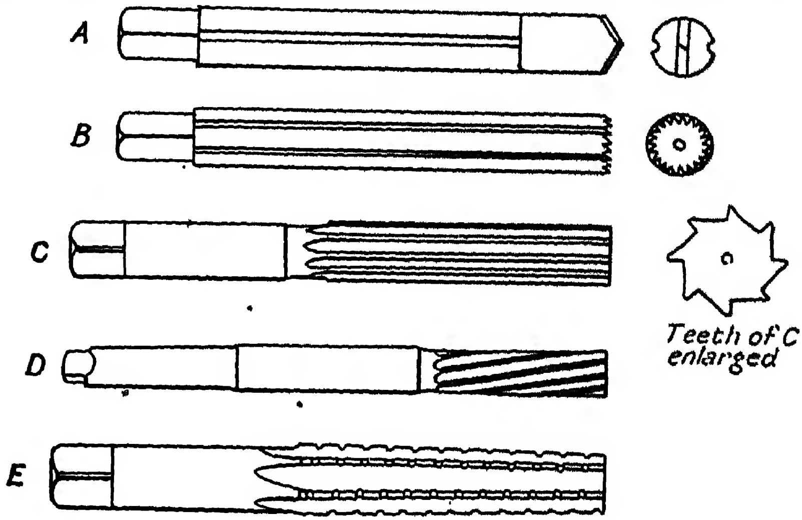


FIG. 27. TYPES OF REAMERS

as is also the next example, *B*, the old rose reamer, an excellent tool for accurate and fine finishing. It only cuts by the teeth on the end. The grooves allow the oil to spread well over the body. A modification of the half-round reamer is occasionally used, consisting of a cylindrical body with three or four teeth cut along one side, leaving the other half of the circumference to act as a steady in the hole. But in most instances a full set of teeth is cut around the body, *C*, both for parallel and tapered kinds. Sharpening is done on the cylindrical grinder or in the lathe, and a fine edge completed with the oilstone. Chattering is usually caused by

attempting too heavy a removal of metal with the reamer, or by reason of the teeth possessing excessive clearance. An idea often practised is that of spacing the teeth irregularly, instead of at exact equidistant parts of the circle. If chatter marks begin to form through a hole, a regular-spaced tool will tend to increase these in magnitude; but irregular spacing allows succeeding teeth to avoid dropping into the fine grooves, and the hole becomes gradually cleaned up to a perfectly smooth condition. The spiral flute reamers tend to give a smooth hole with less trouble than the straight flute because the inclination of the cutting edges is across at an angle, *D*. *E* illustrates nicked edges for roughing rapidly, as instead of long chips each is broken up into short bits, requiring less power to remove, as well as escaping freely from the hole. A slight taper at the entering end of a reamer enables it to start freely when turned with a wrench, or sometimes a very fine screw thread is cut on the end to draw the tool in. Machine reamers differ in the shape of shank, which is either parallel to grip in a chuck or lathe turret holder, or tapered to fit in a spindle or socket. The long "chucking" reamers are employed chiefly in the boring lathes and the turret lathes, to finish out holes in objects driven by the chuck, and for the larger sizes it is simpler and much cheaper to use a shell reamer, fitted on a mild steel shank of any length desired (see Fig. 28). Another sort of chucking reamer is the three- or four-lipped, which cuts on the end only (like the three- and four-lipped twist drills previously described), but has oil grooves milled around the lands, giving as a result six points of contact around the hole, the result being a very smooth and accurate hole.

All the solid reamers lose their size on frequent sharpening, or through wear. In the case of hand tools this

loss is delayed for a considerable period, but intensive use of the machine class renders maintenance of exact dimensions impossible. Sometimes a second finishing reamer may be kept for the final sizing, in which case a little wear on a first one is not of great consequence, this doing the bulk of the work of correcting the drilled

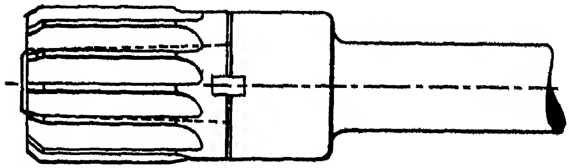


FIG. 28. SHELL REAMER HELD ON LONG SHANK

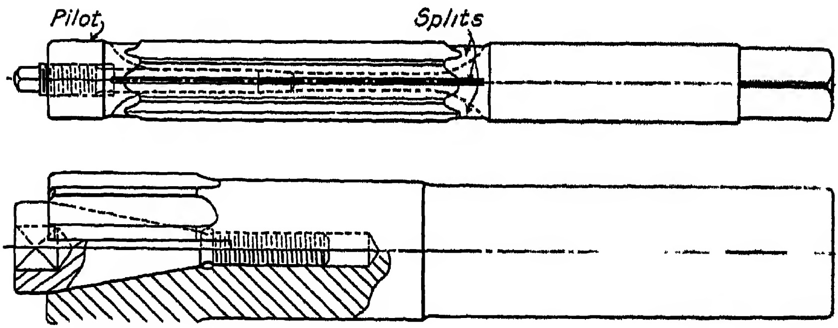


FIG. 29. HAND REAMER EXPANDED BY PLUG, AND MACHINE REAMER EXPANDED AT END

or bored hole. Adjustable or expanding reamers, however, can be set to cut to a precise size, and corrected after the blades have worn down. There are several methods of adjustment, one being to split the body, Fig. 29, and give a slight expansion by means of a taper-nosed plug; the result is a faint bulge along the teeth, but the pilot end guides the tool properly. Short tools may have different mode of construction, which is also shown in Fig. 29. By the separate blade system a much greater range of adjustment can be

obtained, and along the whole length. The simplest style has inclined grooves of dovetail shape, and the six blades fit these tightly, and may be driven up the incline so as to increase the effective cutting diameter. Usually, however, some sort of plug or nut device is preferred, the latter shown in Fig. 30. In the plug

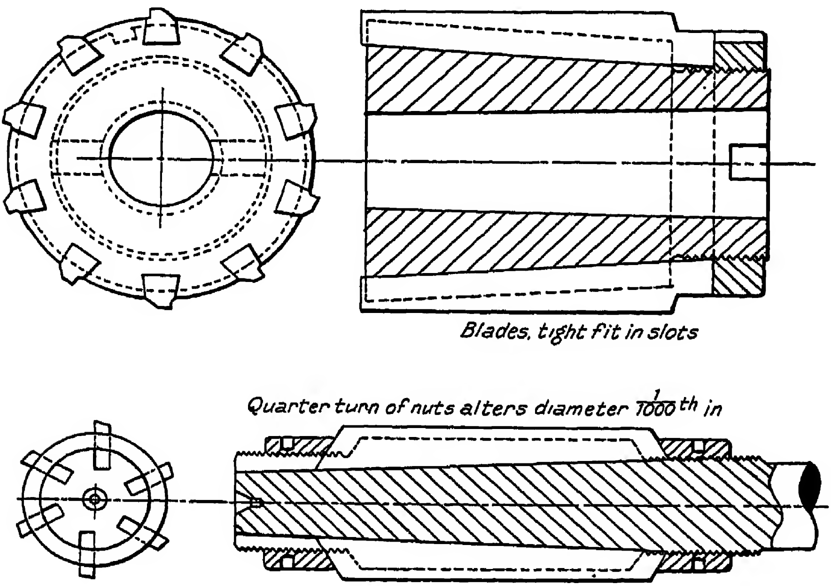


FIG. 30. EXPANDING REAMERS OF SINGLE-NUT AND DOUBLE-NUT TYPES

sort of tool a cone expands the set of blades, and in high-class types there is a micrometer graduation to read the exact increase or decrease of diameter. A further mode of expansion is simply direct—the blades are packed out with tinfoil or hard paper, and the screws tightened again (Fig. 31), after which the reamer is put in the grinding machine and the cutting edges touched off to the desired diameter. This method gives a very solid kind of construction, with a wide range of

adjustment ; new blades are eventually required only after a great number of resettings.

A finishing reamer takes out such a small quantity of metal that a special way of holding it is necessary, to avoid any sort of lateral coercion of the tool. If everything about a lathe or machine were in perfect condition so that the alignment of the reamer was exact, there would be no need for this particular treatment. But spindles, chucks, turret slides, holders, and

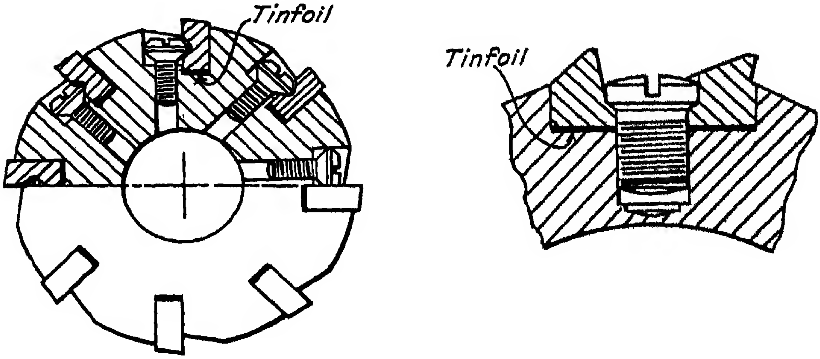


FIG. 31. REAMER BLADE ADJUSTMENT BY PACKING OUT WITH TINFOIL

clamping devices all offer slight opportunities for deflection. Consequently the floating principle is essential, and consists in the simple device of attaching the shank (or sometimes a shell reamer on its arbor) loosely, so that it may follow the hole quite freely and take an equal cut all around. A fastening is detailed in Fig. 32 ; the play must not be excessive, otherwise the reamer end will sag too much, and not start properly at the mouth of the hole. Frequently the end pressure is taken upon a ball point, or a centre is fixed in the back of the socket so that this centres the shank and gives good results. The weight of a long shank and heavy reamer has no effect when

used in the vertical attitude, but, horizontally, it causes sag, and a slight tendency to cut the hole too large. Heavy floating fittings are therefore made with one or two spring pads beneath the shank to take the weight and keep the tool in the central position for starting, without afterwards interfering with its float. Another device consists of a ball and socket fitting, backward pressure being exerted against this by springs, also keeping the tool central at first. When a reamer is

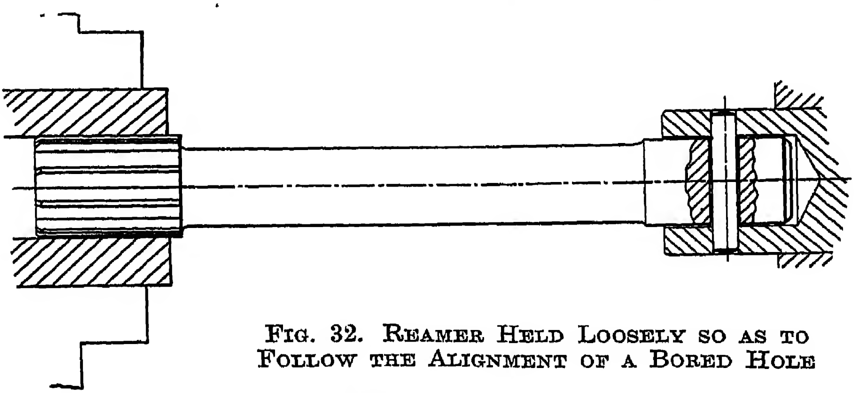


FIG. 32. REAMER HELD LOOSELY SO AS TO FOLLOW THE ALIGNMENT OF A BORED HOLE

hollow to conduct lubricant to the point, the supply may be pumped through the holder.

COUNTERBORES

The parallel enlargement of the mouth of a hole for a certain distance as distinct from countersinking, which implies a conical recessing, is done differently according to the size. The large holes which are made by boring can be counterbored with simple flat cutters. In large holes the cutters go in a head. Piloting is done by direct fit of the bar in the hole in turret lathe and vertical lathe practice. The small counterbored holes require a tool with sufficient stem to act as pilot; some are made in one piece, but it is often better to fit an inserted cutter. This permits of doing different

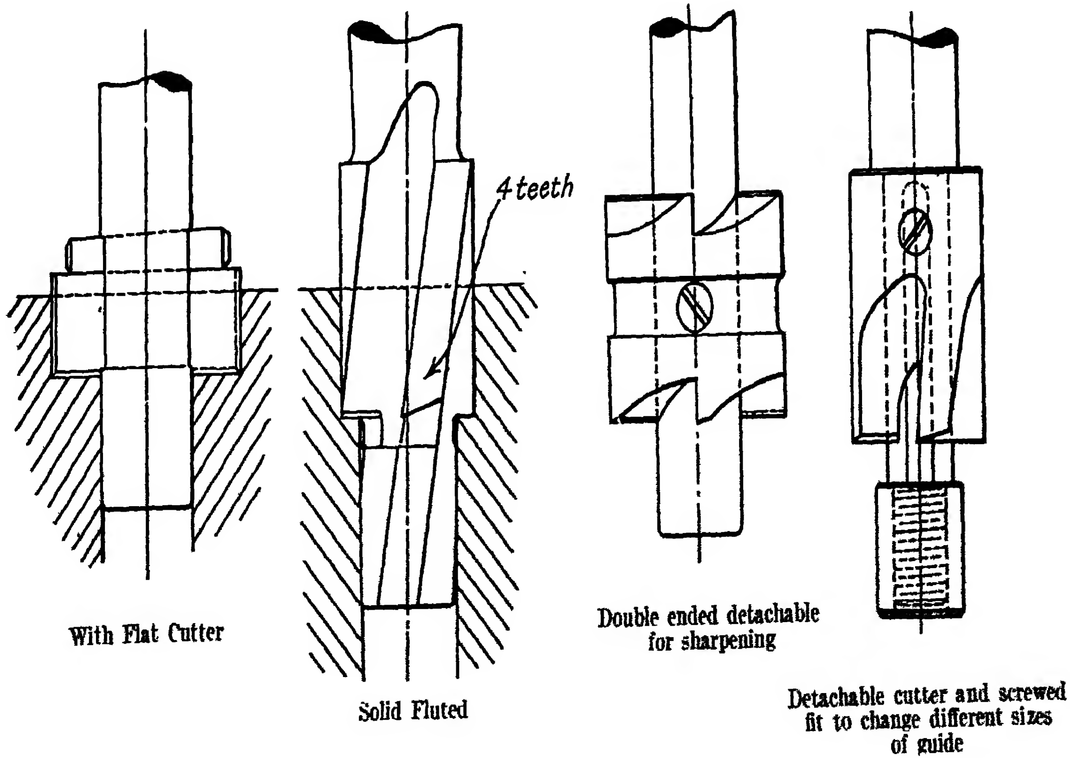


FIG. 33. COUNTERBORES

diameters, and in case of the cutter breaking a renewal is easy. The pilots are also removable in many designs, being made as bushes, to provide various sizes. These features are illustrated in Fig. 33.

COUNTERSINKS

A good deal of rough countersinking, especially for rivets, is performed with a flat drill of suitable angle. This is quick, and the tool is cheap and easy to sharpen.

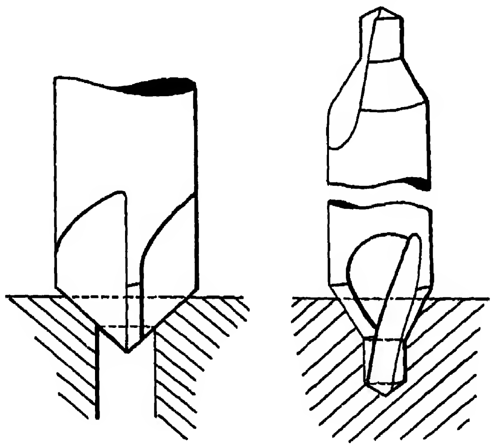


FIG. 34. COUNTERSINKING TOOLS

It does not always give a smooth or accurate finish, and is not good enough for many purposes. The alternative is either to provide a steadying influence in the form of a pilot, or to increase the number of cutting edges, the former method being common in turret lathes. The cutter is then either fitted direct in the bar, or is made in two parts, and held on each side of a head for large diameters. A four-lipped tool is shown in Fig. 34, also including the combination drill and countersink, which is invaluable for putting centre holes in work to be mounted on centres.

TREPANNING

Such an operation becomes essential when a fairly large hole has to be cut in thin material, or a lot of metal taken out of a solid block. In either case, the

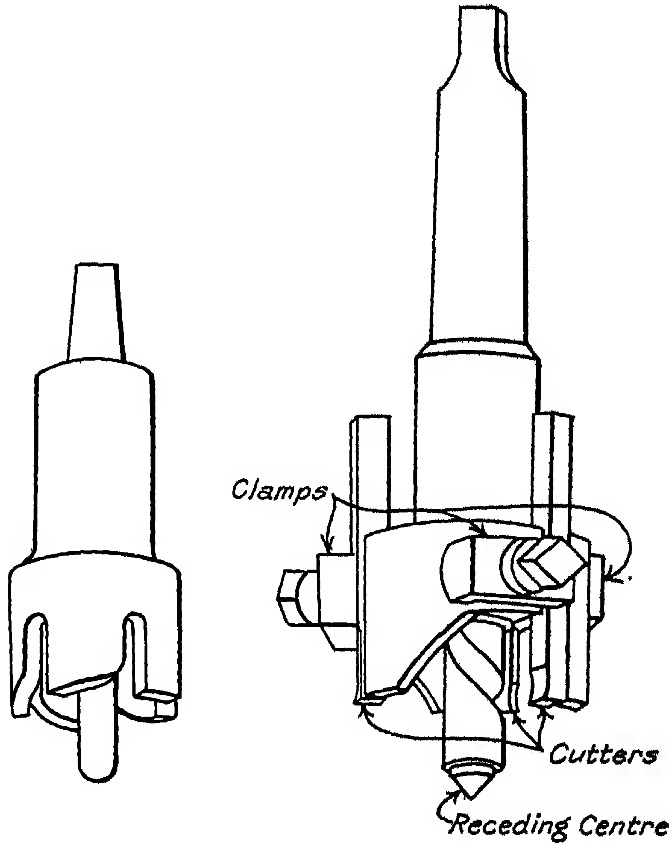


FIG. 35. TREPANNING TOOLS OR PLATE DRILLS (*Selson*)

labour of drilling or boring out so much metal in the usual manner is unnecessary. Plumbers and others who handle sheets and plates for tanks and various vessels employ a cylinder saw, or simple tool of the

style represented in Fig. 35, but for continued use in drilling machines tools with two, three, or four removable cutters are chosen. The cutters are firmly clamped in the manner depicted also in Fig. 35, and are perfectly supported by the curved portions of the body. Sometimes a preliminary hole is drilled in the plate

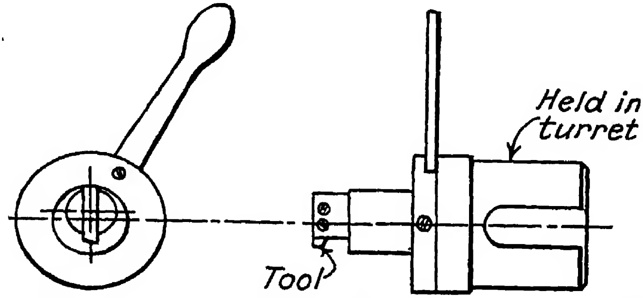


FIG. 36. ECCENTRIC RECESSING TOOL WHICH IS FED RADIALLY INTO A BORE TO CUT A RECESS

for the pilot end, but the class of tool shown has a point centre that just needs a heavy centre-pop in the plate for location. The centre recedes into the shank as the disc of metal is gradually cut out.

RECESSING

This is a process mostly effected in the lathe, one of the chief reasons being to provide a free space for a threading tool or tap to clear into. A tool from the slide rest (or the cross-slide of a turret lathe) may be of simple bent form, like *B* in Fig. 23, of suitable width. Quicker application is, however, made if the tool is slid up by the turret, and then fed outward to the required distance when it has entered the proper depth into the hole. For small tools, an eccentric or a swing action gives the radial throw, while heavier sizes have a straight slide, moved by lever or screw, this principle being also suited for facing. An eccentric type

may be observed in Fig. 36; the amount of throw is regulated by a stop screw.

THE MEASUREMENT OF BORES

It is not such a simple matter to ascertain the size and condition of a drilled, bored, or reamed hole, as it is of a turned or ground bar. There are four ways: by ordinary leg calipers, by micrometer calipers, by rod gauge, and by plug gauge. The first named require to be applied carefully, so as not to get the tips across the hole either in the forward or the lateral direction—careful sensing of the touch is necessary while the tool is held delicately, as shown in Fig. 37. The micrometer caliper is either of beam class, with narrow jaws for entering small holes, or of bar type (Fig. 38), or else of straight style, the measuring tips being in line with the body of the tool. One kind of this last seen is in Fig. 39. The rod gauge is a simple piece of round steel with rounded tips, to measure a single size, or if fitted to slide in a socket, a range of diameters. The plug gauge is also a fixed tool, and has the advantage of showing whether the hole is fairly true as regards roundness and parallelism. In repetition work limit gauges are employed; the oversize, or "not go" end, must not enter the hole, and the "go" end must do so. If the first enters, it means that the hole is too large for the specifications, and if the second does not enter, it means that the hole is too small. Tapered holes have their appropriate tapered plugs.

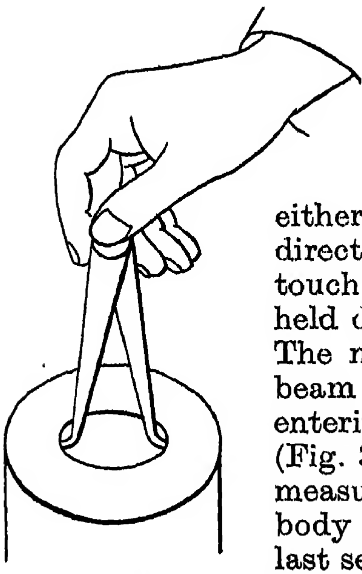


Fig. 37. Mode of Holding Calipers

JIGS AND FIXTURES

The primitive method of starting a drill, or of adjusting a boring tool or its work to position by reference to a centre-pop, or a scribed circle is suitable for all operations on general work, but it is not good enough nor economical when a quantity of pieces require to

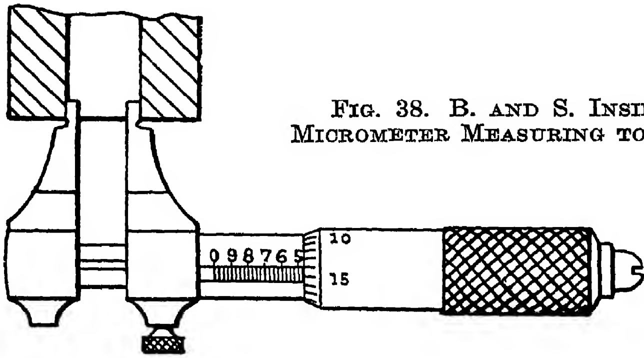


Fig. 38. B. and S. Inside Micrometer Measuring to 1 in.

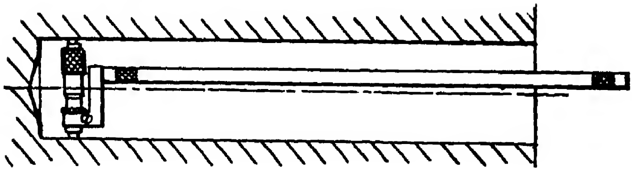


Fig. 39. Johansson Inside Micrometer with Handle Attachment for Deep Holes

have similar treatment to specified limits. Drills must therefore be located and guided accurately, or bars guided in an appliance which ensures the work always occupying the same position. The variations in practice depend on the shape and size of the articles, and sometimes the length of the holes. Some bores for instance may be done with a bar piloted at one side of the piece, while in other cases the bar must have support on each size of the work. The simplest drilling jigs are pieces of plate clamped on the flange or

other element to be treated; the most elaborate are enclosed boxes with hinged covers, and numerous drill bushings on the various sides; such a jig is either turned over successively on to the drill table to expose the several flanks to the drills, or is mounted in a swivelling holder.

Fig. 40 explains the principle of a simple jig with no means of locating, this being just set concentric with

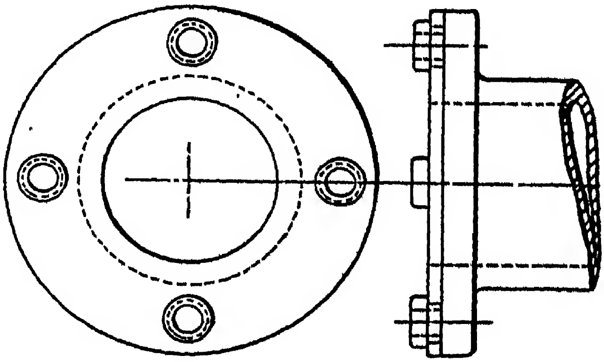


Fig. 40. Drilling Jig Set by Hand

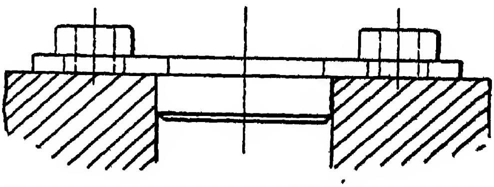
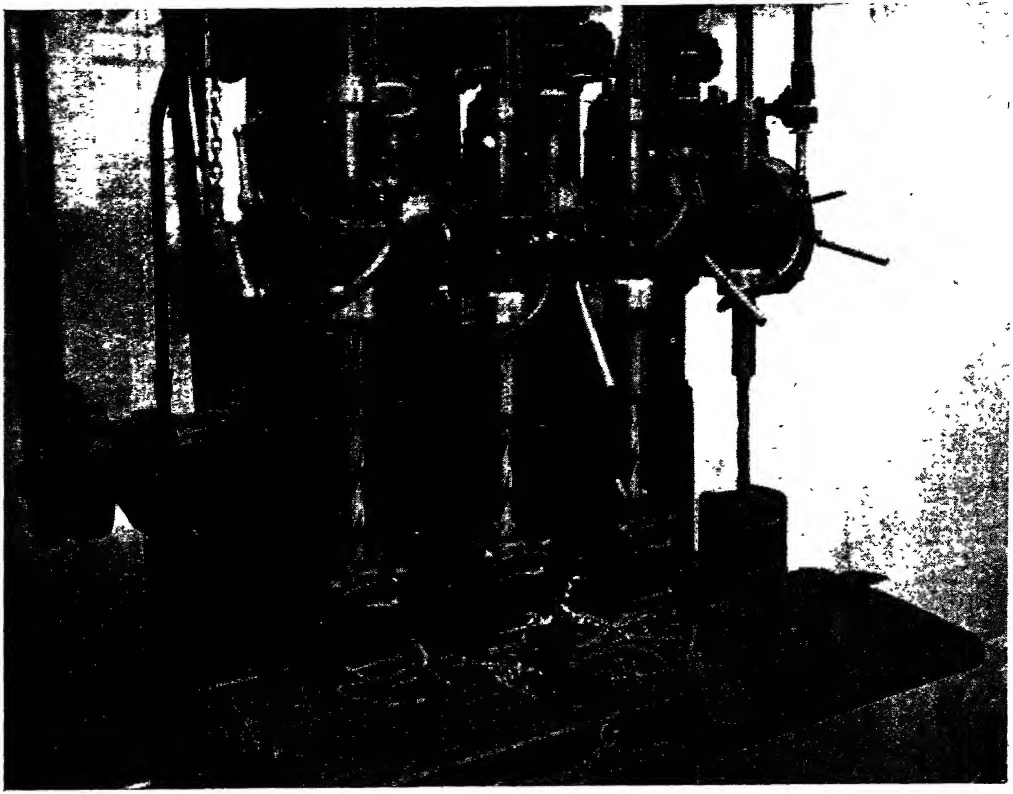


Fig. 41. Location by Turned Spigot

the outside or the inside of the flange, and secured by a couple of screw clamps. As a reasonable depth of guidance is necessary for the drill, preference is usually given to fitting bushes as shown, rather than making a very thick plate. The bush method makes a cheaper and lighter jig, and the bushes can be made of the best material, hardened, and renewable when worn. In many cases, though not in this example, bushes lift



(*Alfred Herbert, Ltd.*)

FIG. 42. SIMPLE JIG SYSTEM FOR DRILLING STEEL PLATES ON BALL BEARING DRILLING MACHINE

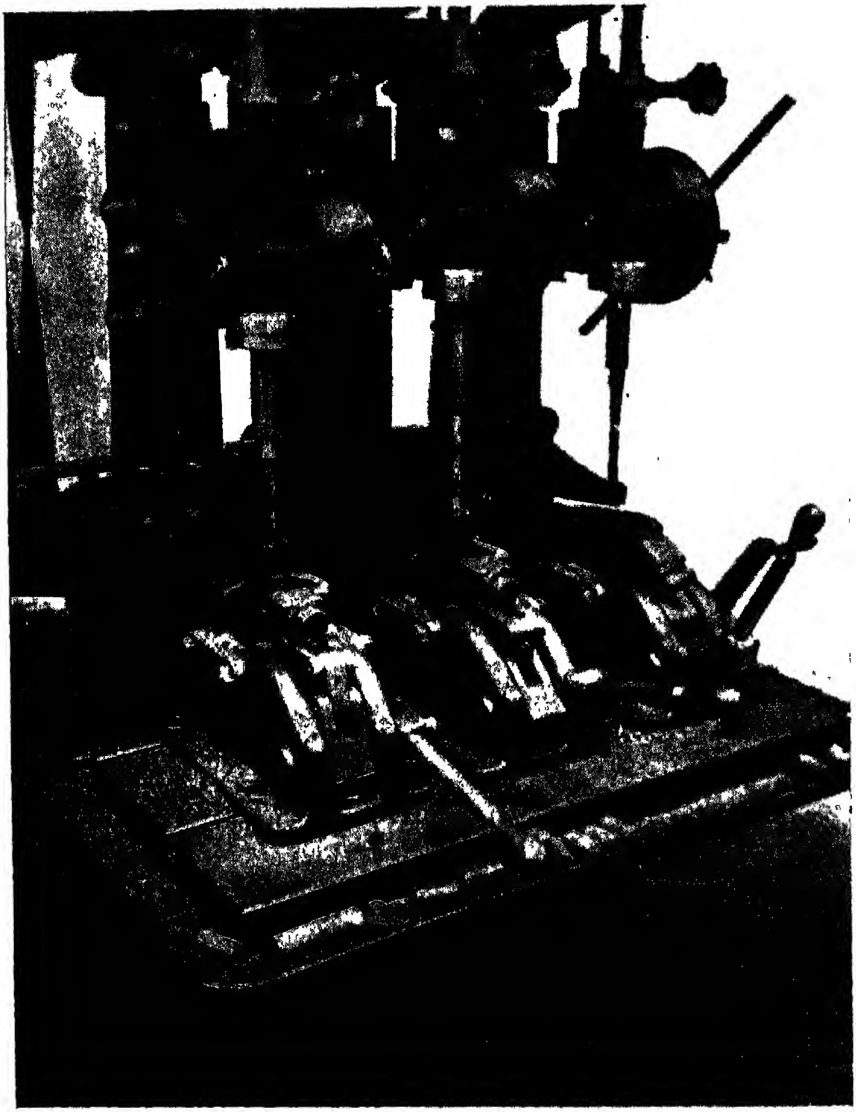


FIG. 43. QUICK-ACTING TOGGLE GRIPS HOLDING PIECES IN JIGS ON HERBERT MACHINE

out for the purpose of substituting others, such as to guide first a drill and then a reamer or other tool. The next step in location is that of forming a spigot on the jig plate, such as drawn in Fig. 41, which fits accurately in the central hole already drilled or bored. Such a method acts well for many objects, but there are others where setting has to be done by an outside edge ; this may be effected by pegs fitted in the jig plate and standing down to a sufficient distance. Their number depends on the shape of the article, two being sometimes enough, sometimes three, or more if the contour demands it. Frequently, one or two lateral screws passing through lugs clamp the jig against the work edges, always in a similar position for each unit, the principle being sometimes better suited than ordinary top pressure of clamps.

The manner of location of an object in a jig or fixture depends upon two main factors, firstly the condition of the piece as regards shape, roughness, or variation in sizes of successive units, and whether location has to be made in regard to a finished surface ; and secondly, how the cuttings are to escape. It is no good to provide rigidly fixed locating surfaces when a batch of castings or forgings varies slightly in those dimensions concerned with the setting. Nor is a partly or fully enclosed box suitable for rapid production if the cuttings accumulate within it and clog the locating spots, so that considerable cleaning becomes necessary before the next piece can accurately be inserted. These two main requirements are met by various accommodating arrangements, such as movable blocks or pads or vees, or by a special design of clamp which effects the holding ; and by allowing ample chip space in a box, or making openings for escape. The support of the work upon raised lugs or studs inserted in the metal gives a clearance result, and these spots are readily cleaned off and

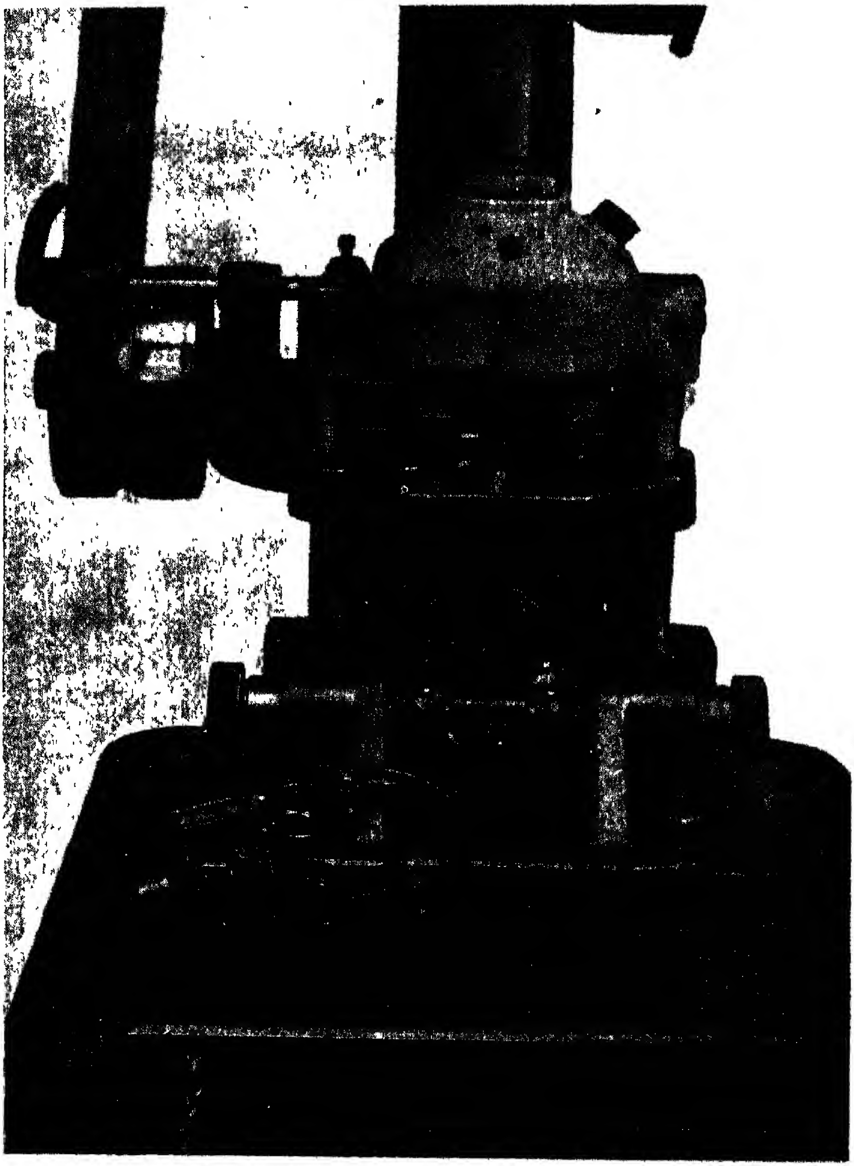


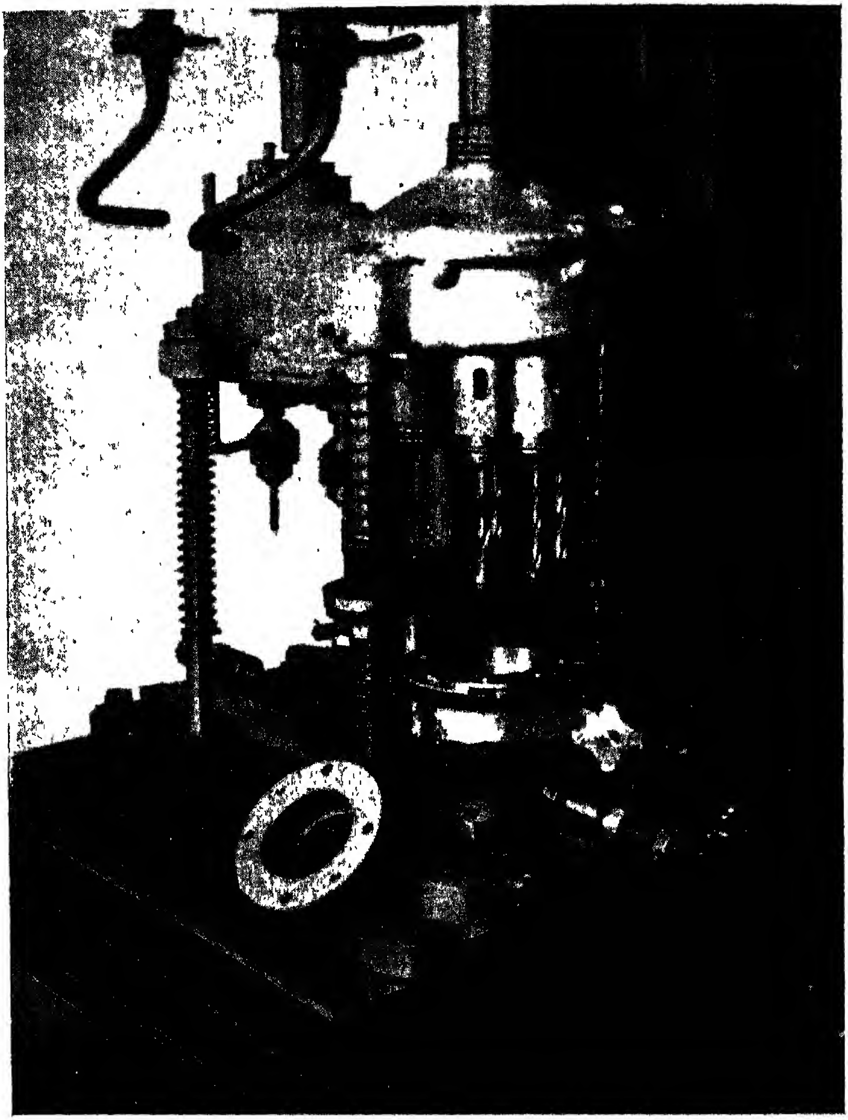
FIG. 44. ALFRED HERBERT DRILL WITH JIG AND MULTI-SPINDLE ATTACHMENT

inspected to note if they are fit for the reception of a fresh article.

The clamps are important details, because upon their quickness of tightening and release the output of the machine partly depends, especially in cases where the drilling, reaming, or boring operation consumes only a short period. The methods comprise pressing directly screws on the work, screw clamps, using ordinary screws, or else those with self-contained handles, avoiding the need for a separate spanner, and cam or toggle devices giving the most rapid action. The instant release of the clamp is secured by these last-named mechanisms, but the screw-tightened clamps must either slide back or swing aside to save time. Many jigs have hinged covers, tightened with one or two wing-nuts, and the cover thus acts as a clamp as well as for holding drilling bushes (see Section XXI).

The following photographs serve to explain many interesting points about jigs, in a rather clearer fashion than would be possible by means of drawings. Figs. 42–46 illustrate equipment on the ball-bearing drilling machines made by Alfred Herbert, Ltd., of Coventry. Very simple fixing occurs in Fig. 42, where steel pieces are simply pushed into the jigs, and the drills brought down by means of the hand levers. An automatic or self-engaging feed comes into action the moment a drill touches its work, and this continues to the desired depth, upon which the feed stops and the spindle goes back up to its original position. One operator can thus without undue fatigue keep the machine going, at an output of eight pieces per minute, the drills being $\frac{7}{8}$ in. diameter.

Fig. 43 shows an ingenious method of holding circular pieces, this being done by means of levers working on the toggle principle, giving a tremendous grip, and being rapid in action. The objects shown can be drilled



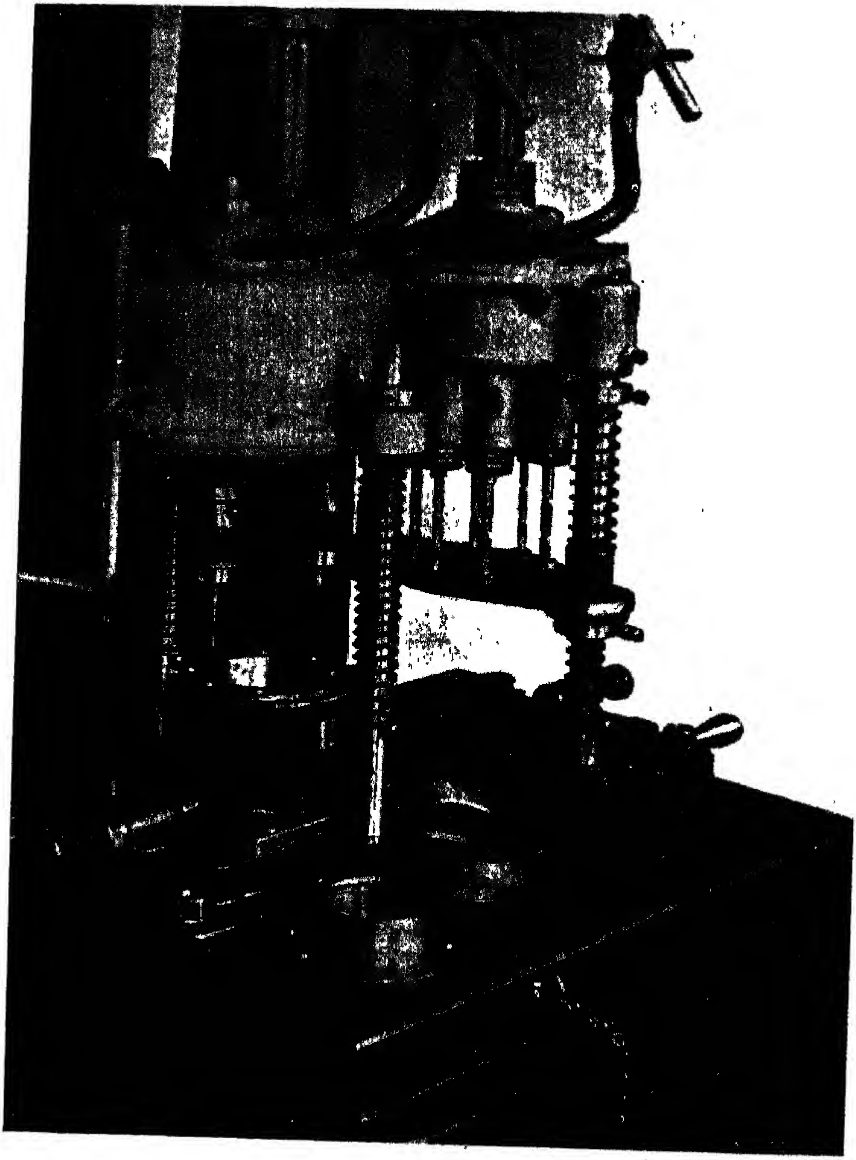
(*A. Herbert, Ltd.*)

FIG. 45. MULTIPLE DRILLING AND TAPPING HEADS FOR CLUTCH-PLATE

at the rate of one in 15 seconds at each spindle, one attendant comfortably looking after the three jigs. It will be noticed that the drill guide bushings are held in brackets attached to the machine uprights. a convenient way to afford the best visibility and freedom from chip choking.

An interesting application of a multi-spindle attachment to the spindle of the ball-bearing drill is seen in Fig. 44 ; this drills and countersinks five holes in a carpet-sweeper frame, shown in the jig, and also loose. The method of location is by a hole bored in the back of the fixture for the spigot of the sweeper frame to fit in, and then the two knurled knobs at the sides of the fixture are turned to close in the locating pegs entering holes already drilled in the two bosses. The piece is thus located in exact position for the drills to enter. An important feature of the equipment is the use of guide pillars and a jig-plate, which lies between the pillars, and is carried on a stud fixed in the centre of the drill-head, this stud being visible between the front drill-spindles. Thus the drill-head, the jig plate, and the jig base are all connected and maintained in perfect alignment. The action of this combination is as follows: After the work has been locked in the jig, the machine spindle is fed down and the jig-plate comes into contact with the work. Then the five drills operate until the proper depth of holes has been reached, and the countersinks made to the correct size. On raising the spindle the drills withdraw from the piece, and the jig-plate is picked up with the drill-head, leaving the work free for removal and the insertion of a fresh piece. The time taken to drill and countersink is 15 seconds, or four units a minute.

A fine example of the application of multiple drilling and tapping heads may be studied in Figs. 45 and 46. The machine is of two-spindle type, driving a



(A. Herbert, Ltd.)

FIG. 46. JIG SLID TO TAPPING POSITION AFTER OPERATION SHOWN IN FIG. 45

six-spindle drill-head, and a two-spindle tapping head with reversing mechanism. The work, a clutch plate, is held in the jig by a pivoted pad kept open by a spring on the locking bolt. The jig is slid along in the guideways, with a screw top for centralizing at each limit of travel. The drill-head has a locating plate with taper flanges underneath, which holds the work central, and also forms a drill-jig. The actions of the drills, jig plate, and base are similar to those in Fig. 44, but coiled springs are provided to take the weight of the heads and jig plate, so as to relieve the main spindles of the extra weight. The chips are removed through the ends of the jig, whence the flow of coolant also gives a clearing stream back to the machine table and thence through the usual strainers to the tank. Three pieces a minute are drilled and tapped, there being four $\frac{11}{32}$ in. holes and two $\frac{11}{64}$ in. holes the latter being tapped to $\frac{5}{16}$ in.

Fig. 47 deals with the jig system for a fairly heavy component, the gear-box for a commercial motor vehicle. There are three separate settings, that illustrated being for the first. Messrs. J. Archdale & Co., Ltd., of Birmingham, made the equipment to suit one of their large multi-spindle machines. The drilling-plate is mounted on spring posts so as to leave the jig clear for unloading and loading directly the operation has been completed. A trough is cast round the plate, which being flooded with the coolant guarantees an ample supply to each spindle with a minimum of piping. The jigs are placed upon an indexing table and, as the drilling at one jig finishes, the table is moved along on rollers and a stop sets the second jig under the drills. As these again operate, the other jig is unloaded, and a fresh case laid in, ready for running the table back, and so on. Fig. 47A shows a close-up view of the sliding jig plate on the machine illustrated in Fig. 47.

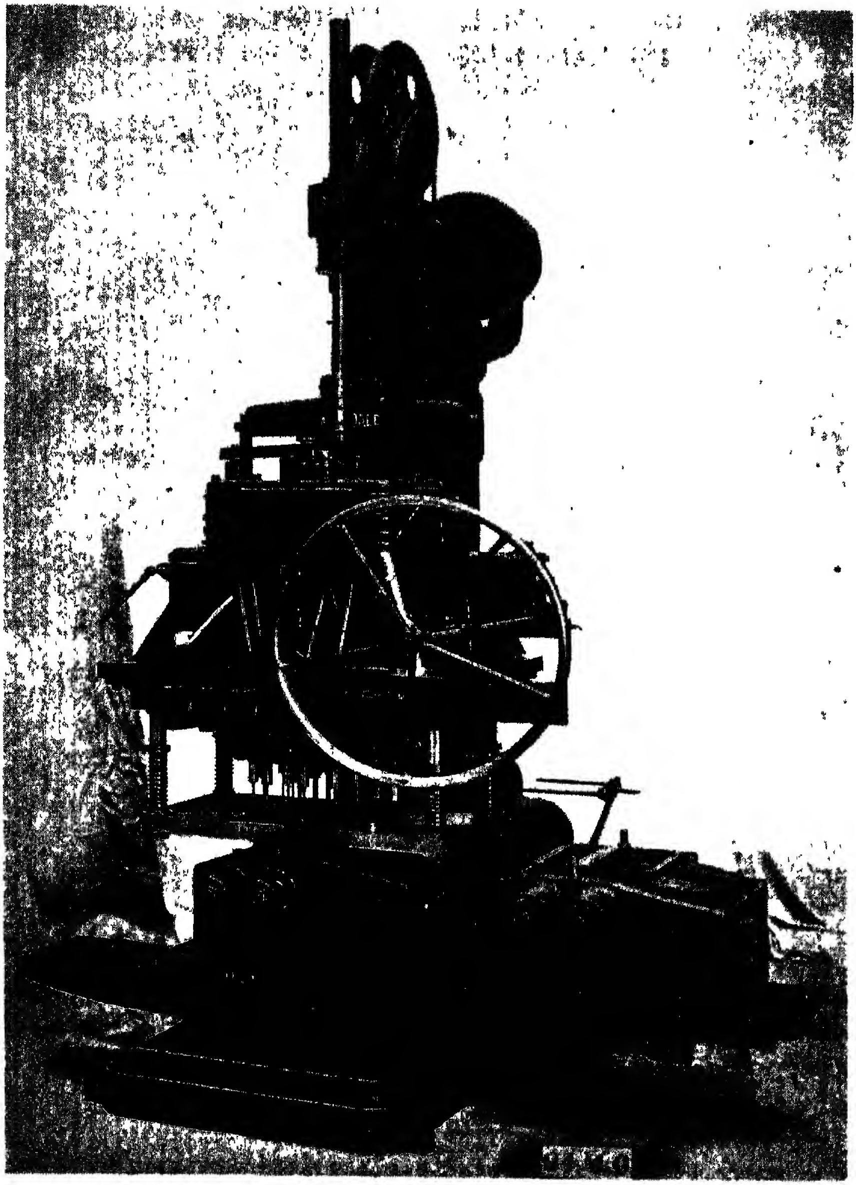


FIG. 47. ARCHDALE MULTI-SPINDLE MACHINE WITH DUPLEX JIGS FOR GEAR-BOX DRILLING

A fixture holds work, but does not guide the drill or other tool in any way. Its use in the drilling machine is chiefly confined to holding pieces in which the position of the drilled holes is not required to be very exact, or the drills are very short, or are of the countersink class. But for work such as counterboring, some kinds of reaming, many sorts of boring, and sometimes tapping, a fixture is suitable. In the lathe especially it is very valuable for receiving objects not suited to go in the chuck jaws, to be drilled, bored, reamed, as well as turned and faced. A great many such fixtures are of the angle-plate type, a casting or forging being held by a foot or flange on an angle plate, with appropriate locating elements in the way of strips, studs, screw-points, a spigot, or other surfaces. For a moderate run of like pieces the angle plate can be of standard type suitably fitted up, including the clamps, but special plates are cast for large outputs, many being of a cradle form to take the work better and apply the holding clamps. The necessary balance weight is either cast on the plate, or attached with screws, the latter being often the more convenient way, both for purposes of machining the fixture and of making alterations for different sizes of work. Also the plate is often cast with a circular foot to bolt to the face plate or chuck face.

An indexing fixture possesses sliding or swivelling action for the purpose of placing the article in two or more positions to deal with holes either lying parallel or at angles with one another. This type is very useful for handling difficult shapes that require several operations in the turret lathe, with close limits. Fig. 48 depicts a neat construction of sliding fixture to locate the bores of a twin motor cylinder (H. W. Ward & Co., Ltd., Birmingham) for one of the firm's turret lathes; the operations include boring, bottoming (with the tool

seen), reaming, bell-mouthing, and facing. The cradl in which the casting is located and clamped has a cross sliding movement on its base, with hardened and groun steel plugs fitting in bushes for exact location. Th

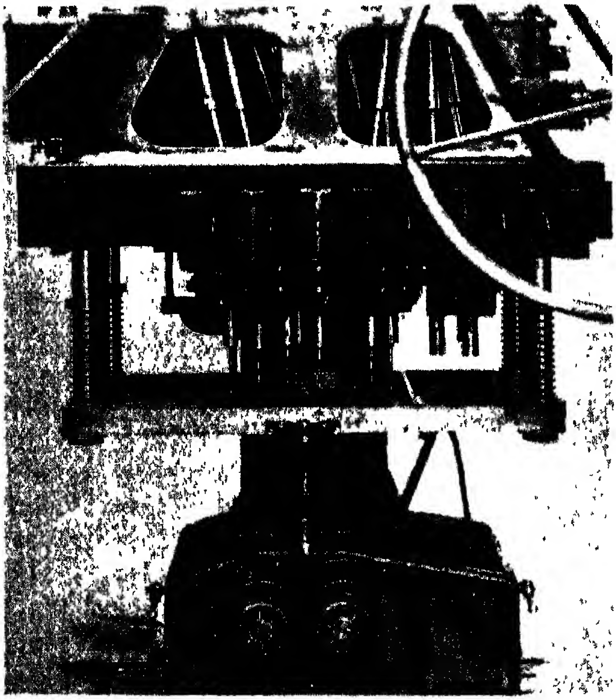
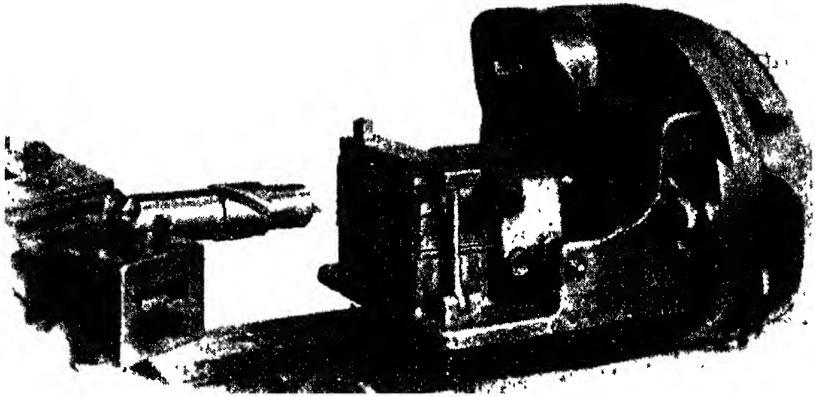


FIG. 47A. CLOSE-UP VIEW OF MACHINE ILLUSTRATED IN FIG. 47, SHOWING DETAILS OF THE SLIDING JIG PLATE

slide is locked by a binding strip to avoid undue pressure on the locating plugs. The change of position is effected by means of the part pinion and rack, using a tommy handle in a hole in the balance weight which is attached to the pinion. The weight is so arranged that its partial swing brings it into the correct position for balance in either of the two settings.

MACHINES FOR DRILLING AND BORING

For most ordinary operations, the two factors governing the type of machine used are the size of the work and the size of the average hole. Some bulky pieces are put on machines which only operate small drills, while quite small pieces may be handled in



(*H. W. Ward & Co., Ltd.*)

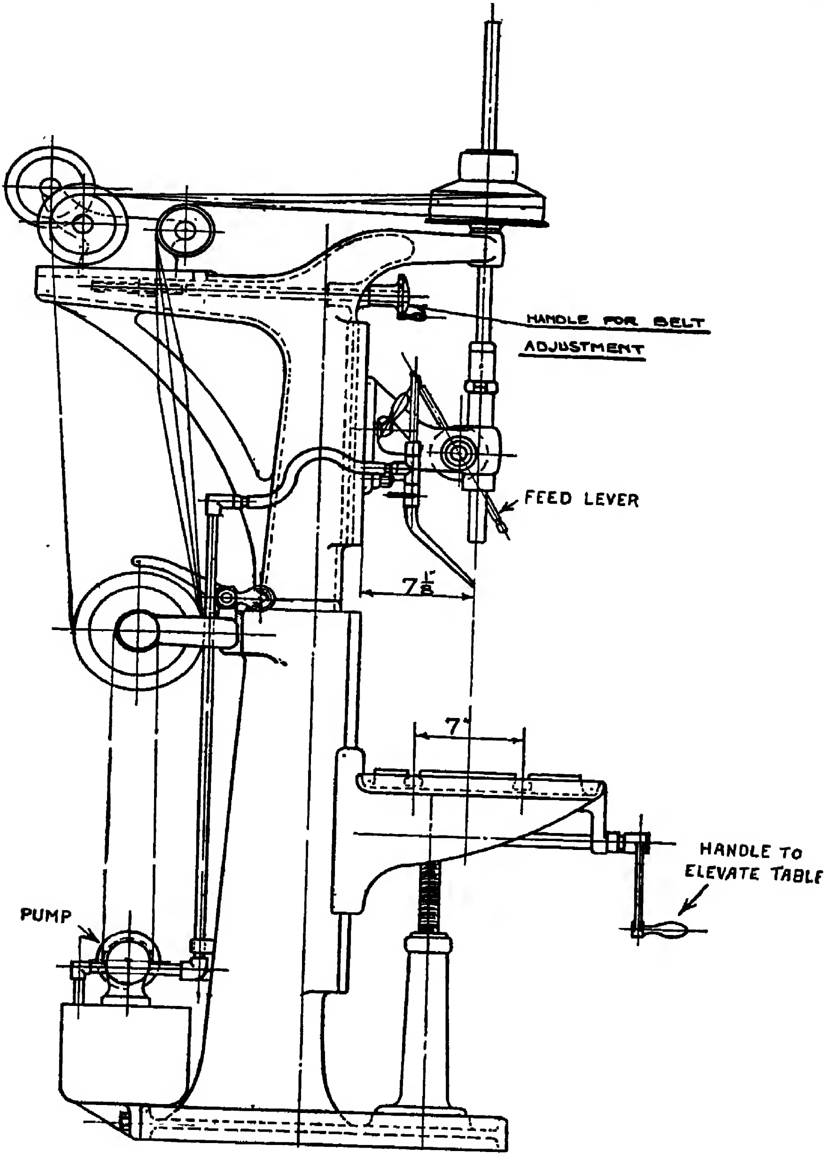
FIG. 48. SLIDING FIXTURE FOR LOCATING THE BORES OF A TWIN-CYLINDER ENGINE CASTING

machines making large holes. These two conditions are, however, the exception rather than the rule, and a small machine generally drills or bores small objects, a big one, large castings and forgings. The tiniest drilling appliances are the portable pneumatics, held in one hand, and weighing about 2 lb., and the largest machines for drilling and boring those of the travelling standard type which operate on huge castings while in a fixed position on a floor plate of considerable area.

The spindle saddle travels up on the column to a height of about 15 ft. from the plate level. Another huge tool is the boring and turning mill, the largest swinging work nearly 50 ft. in diameter.

Portable machines comprise the hand-geared drills, the ratchet drills, and the pneumatic and electric tools. Some of these are held by the hand alone and forced up; others need a resistance to take a screw-feed against. Large numbers of these appliances are used in both partly finished work and during assembling processes; it is cheaper and quicker to use a portable machine than to carry the work to a fixed machine for a short period of drilling or boring, while as framings gradually assemble and positions of holes are definitely settled the portable drill enables drilling, boring, reaming, countersinking, etc., to be expeditiously done. Reboring of cylinders is another field for the portable machines, the only dismantling necessary being that of the removal of the covers to pass the bar through.

Small fixed drills comprise the hand-driven ones used by blacksmiths and others, and they are rather slow in action compared with those driven by power, and the belt- or motor-driven designs that run at high speeds and give fast production. The latter are sensitive, that is, instead of there being a screw-feed to the spindle, the pressure is given by a lever which enables the cut to be felt and regulated with the least risk of breaking the drills. The best machines have ball bearings to all the running parts, enabling high speeds to be maintained without over-heating. Bench machines and column machines are much alike, but the former have a fixed base, restricting the depth of work, and the latter a table sliding up and down a column, giving a distance of about 3 ft. from spindle to table surface in the larger sizes. A narrow long belt is the favoured



(*F. Pollard & Co., Ltd., Leicester*)

FIG. 49. HIGH SPEED SENSITIVE DRILL WITH PUMP AND FITTINGS

system of driving the spindle, jockey pulleys being adjustable to set the tension, and to alter the position if the spindle pulley has two or three steps. Some machines have a little electric motor with spindle standing vertically at the rear of the column, and a cord or belt on steps gives two or three speeds to the spindle. A speed of 10,000 to 12,000 r.p.m. is quite common in many machines, but much higher rates are possible, these great speeds being necessary in order to impart the correct surface speed to the fine gauge drills. The principal features of a drill are illustrated in Fig. 49.

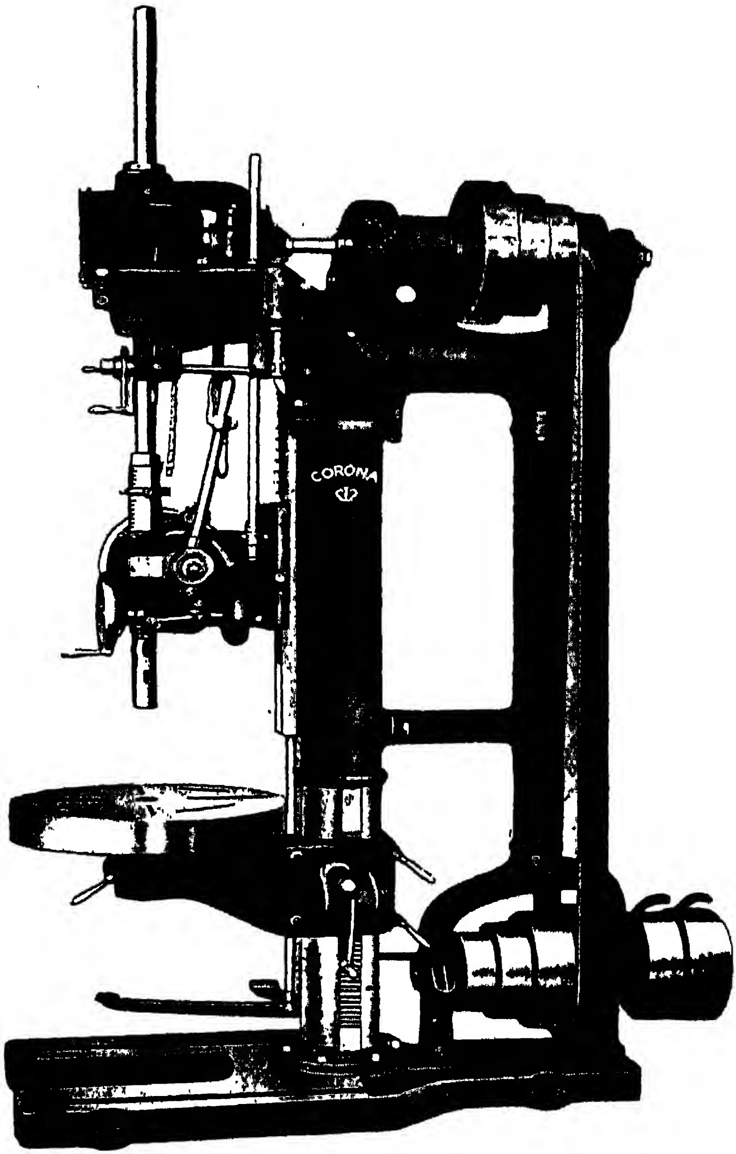
Three variations are noteworthy in regard to the sensitive drill.

The first is that of extension of range to drill over large areas, such being accomplished by fitting the spindle in a saddle adjustable along a swivelling arm, so that the spindle may stand at from 2 to 4 ft. maximum distance from the column. The drive is conveyed by means of an endless belt running over an idler at the outer end of the arm, and jockey pulleys on the saddle to lap the belt around the spindle pulley. Or an electric motor mounted on the saddle eliminates the long belt drive. The second modification is to employ multiple-spindle construction, either two, three, four, or six spindles operating over the one work table. This either enables a different set of drills or tools to be used in rapid succession, or more than one attendant to use the machine. If the spindles are adjustable for distance apart, the machine can be employed for drilling two or more holes in one piece. The third modification embodies automatic engagement of the power feed when the operator pulls the drill down on to the work with the sensitive hand-feed lever. This causes the automatic mechanism which is fitted to the spindle feed to function, as mentioned in connection with Figs. 42 and 43, where it appears.

UPRIGHT DRILLING MACHINES

This term covers a considerable number of types in which the main frame is composed of a cylindrical pillar, or of a rectangular box column. The work rests upon the base plate, or, if of moderate height, upon the table that is adjusted up and down the column. In some cases the spindle head is cast solidly with the column, in others it slides up and down above the table, so as to give an extra range of adjustment beyond the normal feed of the spindle. The methods of feeding the spindle are by direct lever pressure acting on a pinion and rack, by screw or worm and wheel action for greater power, or with automatic feed. A range of speeds is given by cone pulleys or gear-box, with back gearing for the heavier cutting, and a reverse motion for tapping may be incorporated. The different rates of feed are provided by cone pulleys, or preferably with a gear-box, giving ample power and the means of quick selection. The cylindrical pillar on which the table bracket may be slewed gives facility to bring any part of the surface under the tool, in combination with the rotary adjustment of the table by its stem. But when the table bracket fits on flat surfaces on the upright, slides must be added to provide similar setting convenience. If the knee is just plain, the work-piece must be adjusted to position before tightening the clamps which secure it. Should a jig or fixture be employed this automatically sets the piece under the drill, if there is only one hole to be drilled, or there may be a sliding action of the jig for several holes.

The machine in Fig. 50 gives an example of the features of back-gear, six positive rates of feed, and feed by lever or by worm and wheel, and sliding head with movement of 18 in. The spindle speeds range from 22 to 300 r.p.m.



(*F. Pollard & Co., Ltd.*)

FIG. 50. 27 IN. UPRIGHT DRILL WITH REVERSE MOTION BY FOOT FOR TAPPING

The box-body machine has massive construction to withstand heavy drilling continuously, and is often termed a manufacturing machine. Nickel-chrome steel is employed for shafts and gears, and the bearing and lubricating arrangements are designed for severe duties. The stiffness of the head containing the driving and feeding mechanisms is enhanced by the enclosed form of castings used, and the compound work table is adjusted vertically by a screw and supported by slotted braces to resist deflection. These details are seen in Fig. 51. For general duty the machine possesses a 9-speed change-gear box, giving 18 speeds by double gear on the spindle. But if the work is similar for good periods, the change-gear box is not necessary, the occasional speed changes for a new batch of work being made by means of suitable slip gears, which are put on studs to give the desired ratio. The spindle has six upstanding keys or splines cut solidly with it, for the spindle gear to drive, instead of the usual one or two sunk keyways. This gives great durability against the heavy driving and sliding action. All the operating levers are brought to the front, so that the man may effect all changes without moving. The test duty for this machine is that of drilling a 3 in. hole in mild steel at the penetration rate of 2 in. per minute.

There are many designs of upright drills built on the multi-spindle principle, with either fixed or adjustable centre-to-centre distances of the spindles. The framing is sometimes that of the box column multiplied, and a common table for the work, or jigs. The settings of the spindles and the feeds are independent, or may occur in unison, while occasionally it is the table that feeds upwards, such as in the gang drilling machines for girders, beams, and long articles. Clusters of drills are either run in an attachment to a standard single-spindle machine, or the latter is built permanently

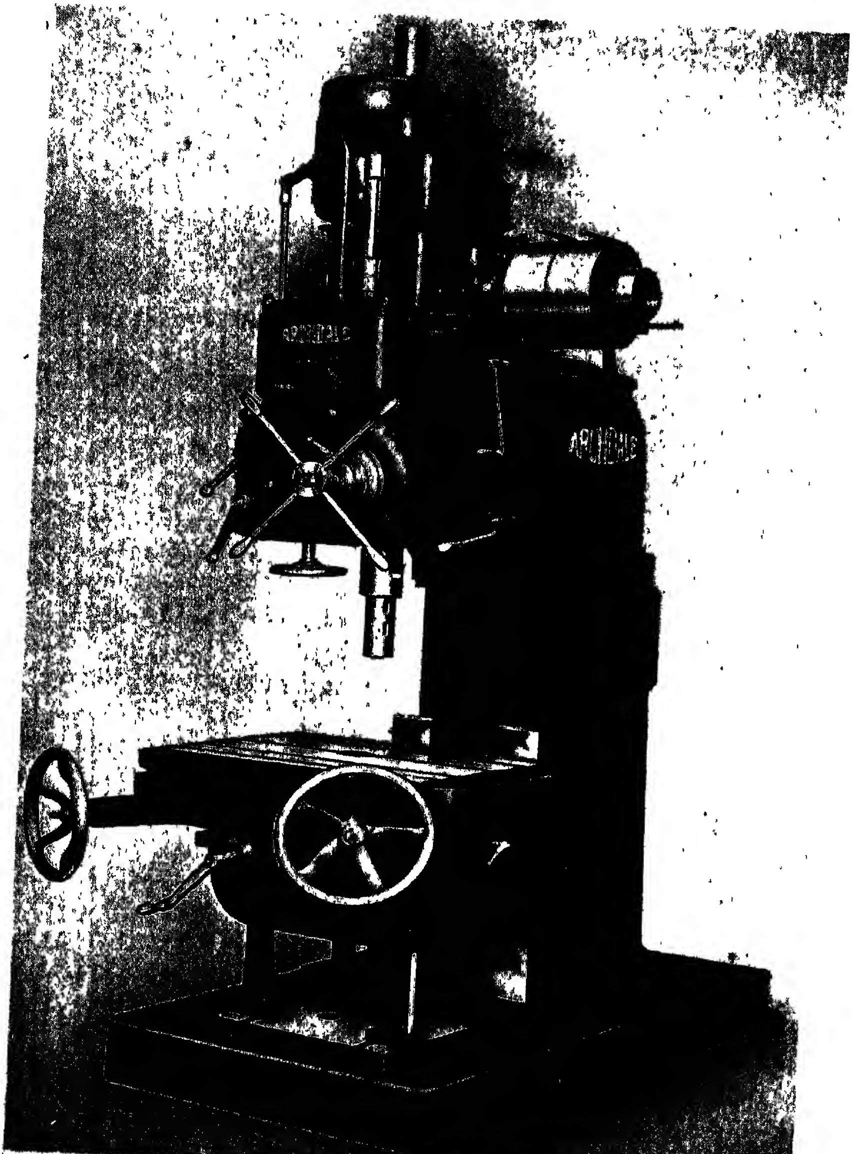


FIG. 51. ARCHDALE 32 IN. HEAVY DUTY "MANUFACTURING" VERTICAL DRILLING MACHINE

with a multi-head. These features may be seen in Figs. 44–47. Many double-ended horizontal machines are constructed with clusters of spindles to drill on two or more faces simultaneously.

RADIAL DRILLING MACHINES

These most useful tools are found in practically every works, because of their range of action; the spindle saddle slides out from the column to a considerable distance, and the arm can be swung to a good radius, often a complete circle. Large areas may thus be covered, or two or more objects can be adjusted and clamped on the base or a duplicate table during the drilling operation. The old objections of difficulty of handling have vanished, and the motions of swinging the arm, traversing the carriage, and of locking and unlocking these are readily accomplished without fatigue. What is termed centralized control enables the attendant to work the drill without moving his feet.

The smallest radials have the arm always at a fixed height, so have the girder or plate radials, which work on constructional steel and do not require the variations in range of height of the machines for general work including castings. The elevation of the arm otherwise necessary is effected by a drive through clutches to the screw, or by an electric motor with the same result. The best machines have the arm clamping device interlocked with the elevating control, so that the motion cannot be started until the clamps are released; nor can clamping be done while the elevating mechanism is running. The Archdale drill in Fig. 52 has a single lever, seen at the bottom of the bright part of the column, which unlocks the arm and simultaneously engages the elevating motion, so that time is saved and accidents are impossible.

A good many holes are usually drilled while the arm stands at the same height setting, but a change of drill position becomes necessary for each hole, hence rapidity of release and re-clamping of the swinging of the arm and the traverse of the saddle is essential to save all

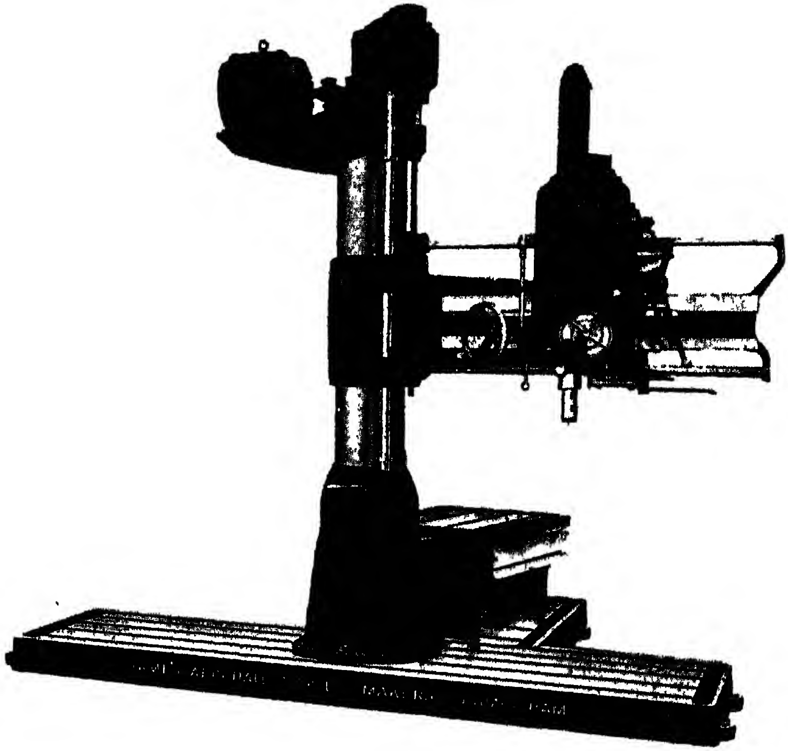


FIG. 52. ARCHDALE HEAVY RADIAL DRILLING MACHINE

the time possible. One lever, named in Fig. 53, binds the saddle to the arm, and simultaneously the column which fits around the middle pillar. The arm is easily pulled round, being mounted on roller bearings at top and bottom. For traversing the saddle, a hand wheel; also named in the photograph, is turned. The change of spindle speed by means of the gear-box built into

the saddle is effected by two levers, while to start, stop, or reverse the direction of rotation of the spindle, the lowermost long lever is moved. Feed changes are selected by one lever, after which another is operated to cause engagement. An automatic trip device stops

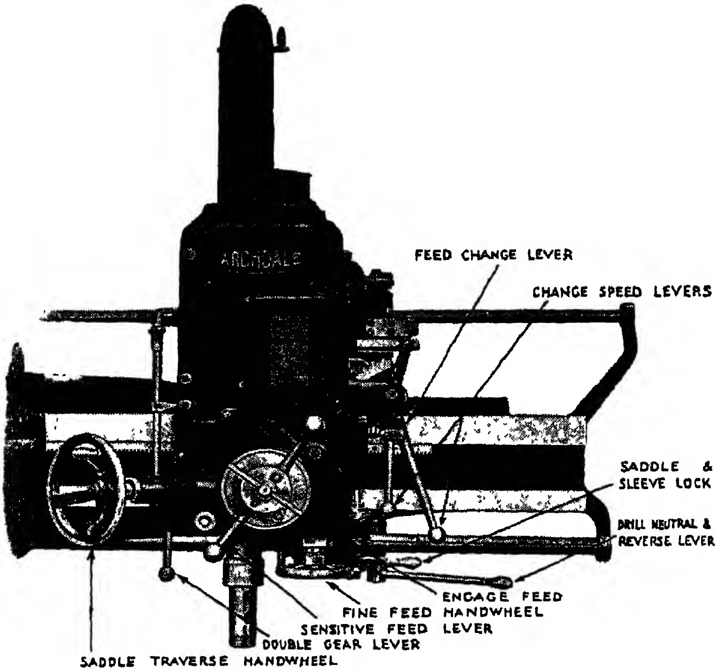


FIG. 53. THE SADDLE OF THE ARCHDALE RADIAL DRILL SHOWING THE CONTROLS

the feed for drilling to a predetermined depth. Hand feed may be given by the sensitive lever, or finely by hand wheel.

It will be noticed that the base plate in Fig. 52 has three work-holding surfaces, enabling setting up to be done while drilling is in progress over one surface. A further advance may be noted in another design, where the column and foot are mounted to travel along a bed.

Thus, three work-tables and a pit can be arranged around the machine, so giving three setting stations and one for drilling, the machine being traversed, the arm swung, and the saddle traversed anywhere over an extensive area, as the traverse along the bed amounts to 10 ft.

The large areas which must be dealt with in drilling plates for boiler and constructional shops require radial machines, often of traversing type, while the work may alternatively be slid on rollers or moved on a trolley. Extra wide plates can be covered without having to use a machine of large radius, by mounting the base on a cross-girder, along which it can be moved, and running the girder on wheels on tracks between which the plate is laid. Any length of plate may thus be dealt with. The greatest degree of mobility occurs with the universal portable radials, supported upon a trolley base, to go anywhere around or on a piece of work, and drill holes at any angles. In some respects it is preferable to employ this machine than to use a small portable electric or pneumatic drill, especially when a number of holes has to go in a large casting or plated structure, or a machine in course of erection. Boring and tapping are included in the operations.

HORIZONTAL DRILLING MACHINES

These are not met with to the same extent as vertical drills, but are chiefly applied to long objects, such as pipes and columns, not suitable for the vertical attitude, and to work around structures such as boilers. The latter have quite special designs of machines, carrying several movable columns to operate on different parts of the shell at once. The marine boiler is supported on rollers in front of the several drills, and is turned intermittently to bring successive spots into position. Special machines are built to drill and

countersink holes in the flanges of flues, the very short spindles being projected out on small brackets and driven with little gears, so that drilling may be accomplished close to the flue periphery. The flue being held in a chuck can be pitched around to the successive locations by an indexing gear and hand wheel to save marking the positions of the holes.

Much horizontal drilling is performed on special single- or multiple-head machines which handle motor components, valves for steam, water, etc., on a repetition basis. Jigs or fixtures hold the articles, and the drills, reamers, facing or other tools attack from each side, or often at three or four locations. Completely automatic operation comprises fast approach of the sliding drill heads, then slowing down to the cutting rate, and finally rapid retirement. Production increases when the work is held in an indexing jig or fixture with an extra station, so that a drilled piece comes out to a position where it can be removed, the jig re-loaded and indexed again to bring the fresh piece into operation position.

HORIZONTAL BORING MACHINES

Great quantities of drilling are performed on the boring machines, as a matter of convenience while the work is set for boring and facing on the larger holes. This is quicker and cheaper than taking the object to a drilling machine, or using a portable drill, and ensures accuracy of alignment and other conditions in all the holes and surfaces. Tapping and the insertion of studs are included in the scope of a great many machines, and also milling.

The necessary adjustment of position of work in relation to spindle is given in various ways. Sometimes the table possesses a vertical adjustment and has a cross-slide, or the table remains at the same level and

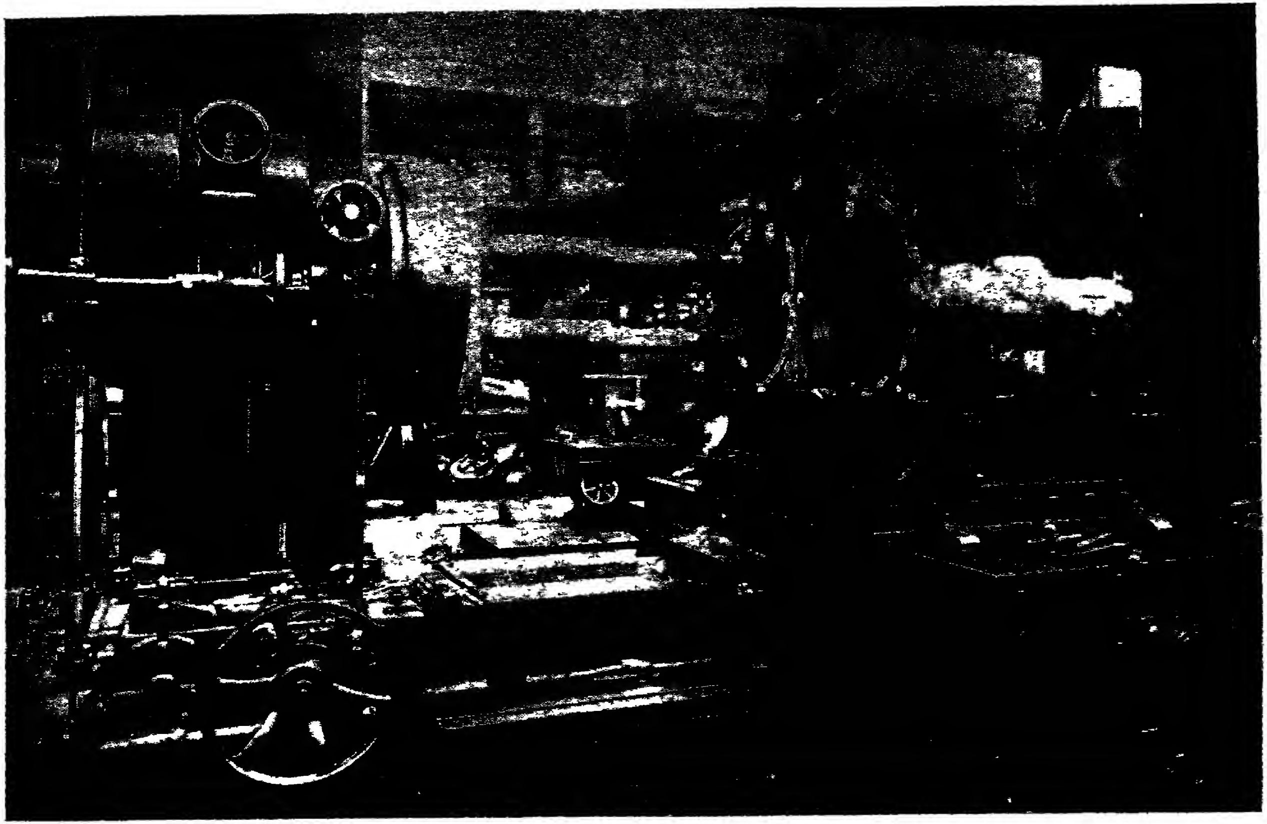


FIG. 54. BORING A LOCOMOTIVE CYLINDER ON THE PEARN-RICHARDS MACHINE

the spindle elevates upon a column. For specially big castings and forgings a large slotted plate holds them immovably, and the spindle is elevated on a column that also has horizontal traverse, or a regular feed for milling. Furthermore, it is sometimes the work table that feeds, sometimes the spindles; often in large types only a cutter head feeds along the massive bar.

The first-named type, with vertically adjustable table, has been developed from the lathe with a gradual sequence of modifications, but the head with its cone pulley and back gears still shows the origin in many such machines. The bar is supported at the free end in an outboard bearing, and is fed through the spindle by power. This class of machine has suffered a partial eclipse in favour of the spindle and column arrangement, a highly convenient arrangement. The most advanced design is that of the Pearn-Richards, by which drilling, boring, facing, milling, turning, tapping, screw-cutting, and grinding may be done. A partial view of the machine is given by Fig. 54, engaged on boring with two telescopic snouts of the class illustrated in Fig. 26, stayed together with a screwed distance-piece and collars. If the ordinary long bar can be passed through the work it receives support in a bearing adjustable up and down a column bolted on the bed a suitable distance along, and the boring feed is given to the table. When work is abnormal in size or weight a modified type of the machine is to be preferred, with a traverse to the spindle, this being more convenient than adjusting the work to the spindle. In certain cases boring may be done while the facing slide is in operation. This slide, for the non-traversing spindle design, is sectioned in Fig. 55, and is shown in the central or boring position, holding the bar socket, such position being set by means of the stop. When a tool holder to hold the square shank of the facing tool is bolted to the tee-slots

on each side of the centre, and the slide fed radially, the tool faces a flange. In the traversing-spindle machine, the spindle is independent of the slide and

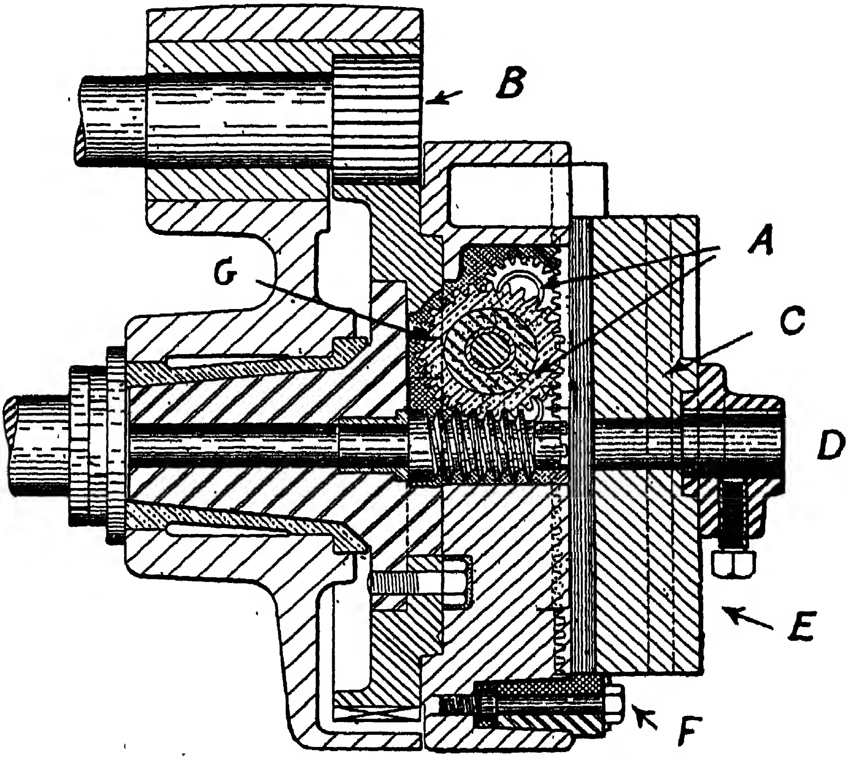


FIG. 55. SPINDLE END WITH FACING HEAD OF PEARN-RICHARDS MACHINE

A—Slide-feed pinions
B—Pinion driving spindle
C—Tee slot
D—Socket to take boring bar
E—Facing slide
F—Centralizing stop
G—Worm gear

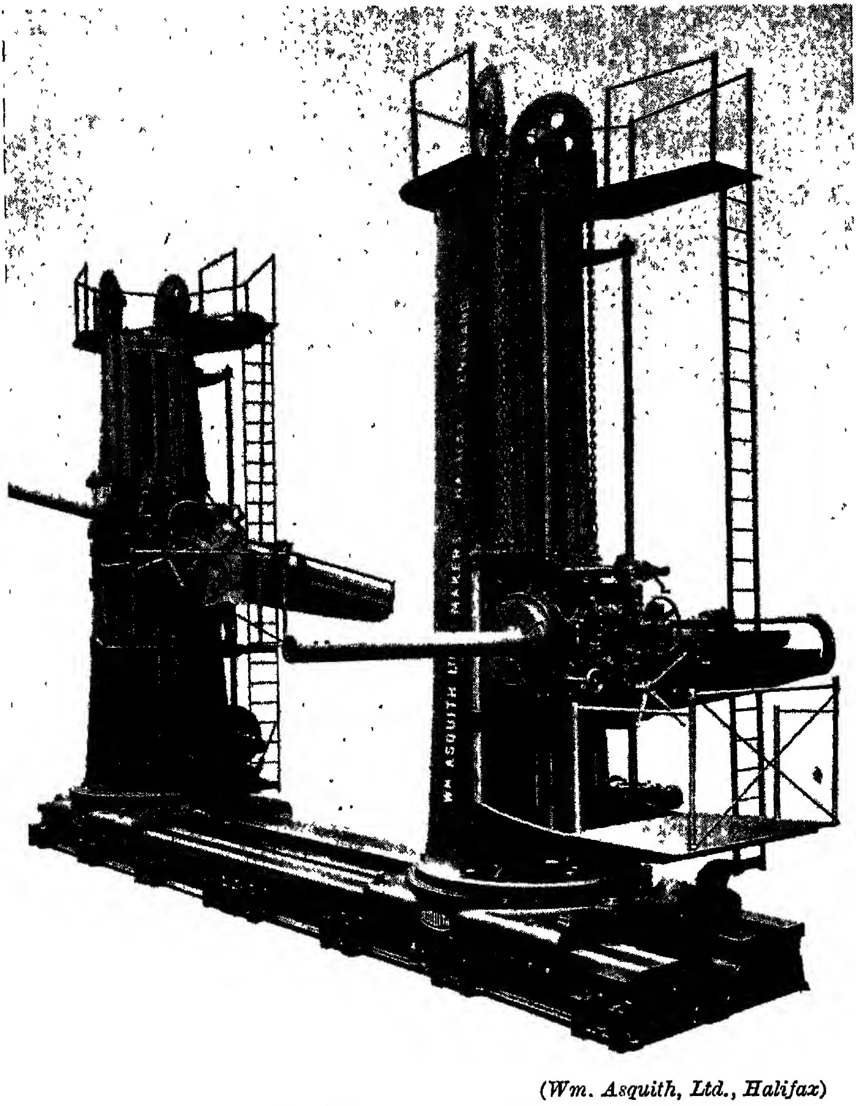
may remain during the facing process. The motion of the slide is derived from the feed-shaft extending through the spindle, thence through the worm gear (which can be de-clutched) to the two pinions actuating the rack of the slide. On extra large work the outer

FIG. 56. ASQUITH 7 IN. SPINDLE DRILLING AND BORING MACHINE BORING ROLLING-MILL BEARINGS

pinion only does the movement. The facing tool is held inclining backwards to give a smooth cutting action, on the same principle to that drawn in Fig. 19. When a milling-cutter is used, the work is fed automatically by the cross-slide, or for vertical movement, by the feed of the spindle slide upon the column.

Several special designs of horizontal boring machines are employed for certain shapes of castings, such as duplex cylinders, cylinders cast with their beds, and beds embodying various arrangements of bearings. When possible, two or more bores are done simultaneously, and often holes at right angles (as in Corliss cylinders). Locomotive cylinders require a two-bar machine, and if the valves are of piston type, two smaller bars for these. Swivel setting may be made to bore the valve chambers at an angular relation to the cylinder bores.

The column class of machine used in connection with a tee-slotted plate of considerable area is useful for big objects (Fig. 56). Instead of making lateral adjustments or feeds with a traversing work-slide, the spindle saddle is travelled by its column moving along a separate slide-way. The length of the latter may be anything desired, but in the big machines usually gives a feed of 15 to 20 ft. It is necessary for the operator to travel with it on a platform attached to the spindle saddle, so that at all longitudinal positions, and all heights, he is close to the spindle for the purpose of working the controls as desired. Frequently two columns go on one slide-way (see Fig. 57), or another is situated on the opposite sides of the plate, or at right angles. In some cases the spindle may be deflected to an angle as evident in one of the heads in Fig. 57, while rotary movement of the column gives facility to bore holes out of parallel with the slideway. These features are seen in the massive Asquith machines seen



(*Wm. Asquith, Ltd., Halifax*)

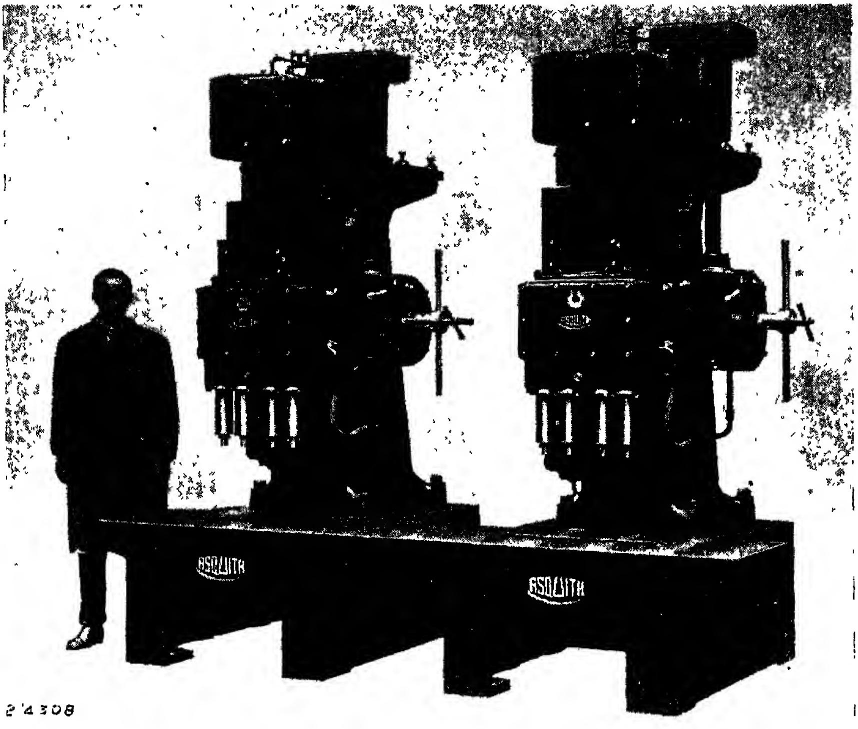
FIG. 57. DUPLEX HEAVY DUTY ELECTRICALLY-DRIVEN FULL UNIVERSAL HORIZONTAL DRILLING, BORING, MILLING, AND SCREWCUTTING MACHINE

in Figs. 56 and 57. Electric driving becomes a necessity in view of the range of action required, and the motors are controlled by liquid starters to ensure the necessary fine adjustments. Portable machines for drilling, boring, milling, or other processes can go anywhere on a large plate to help the work in addition to the column machines on the flanks. The parts of large engines, turbines, and electrical machinery are handled by these massive machines, the floor plate being sometimes made of sufficient area to accommodate several articles. One of the biggest measures 176 ft. long by 48 ft. wide.

VERTICAL BORING MACHINES

The vertical position of bar is chosen for several reasons, one being that a machine built on this design occupies the minimum amount of floor space, another that the cuttings fall down clear of the tools, also the work can often be more readily set, and the setting of the tools and control of their attack be clearly visible. Large vertical machines have long been constructed to bore big marine engine cylinders, held by the bottom flange in the position occupied when erected, so that there is no trouble with packing-up and arranging large clamps as would be required if the work were placed horizontally. For the above reasons the vertical attitude is chosen almost exclusively for automobile cylinder boring, using one, two, four, six, or eight spindles per machine. Sometimes the spindles remain at a fixed height and the work-table is fed up; in many cases the opposite condition is present. The best results are secured when the spindles run in a head without means of adjustment for their pitch or distance apart, but some have adjustable centre distances. The cylinder block goes in a jig with guide plate at the top, and the bottom as well, if the design permits of it.

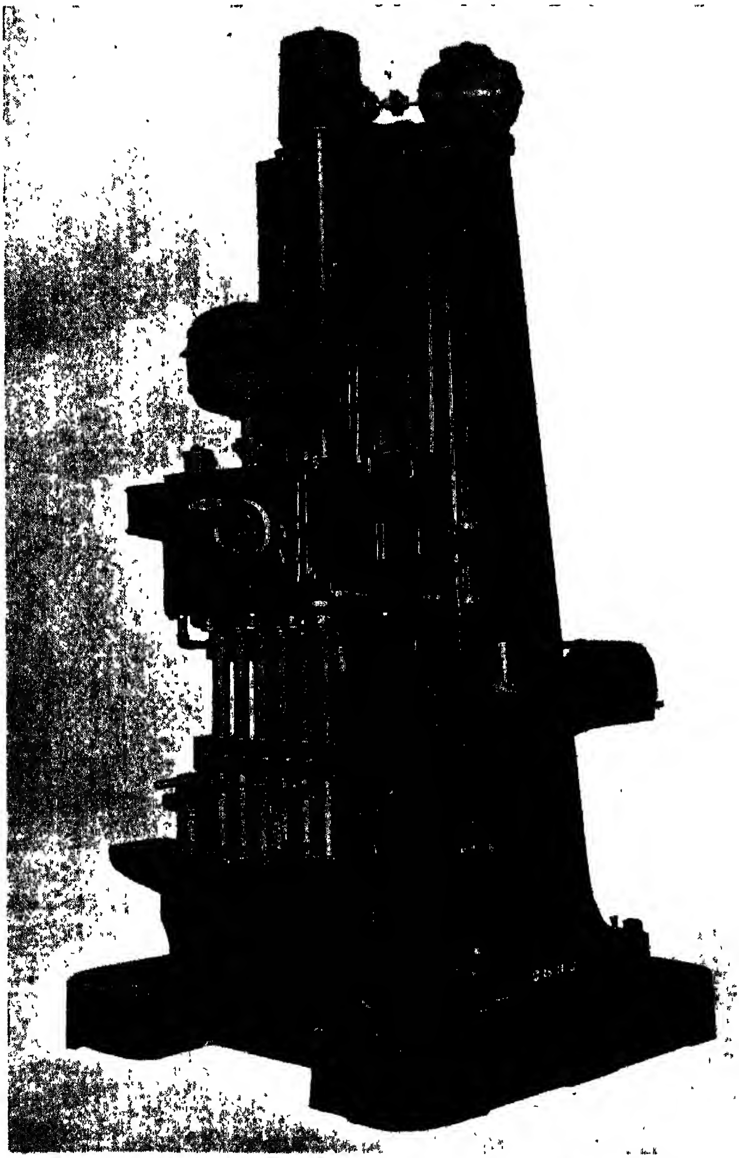
Fig. 59 represents an Asquith machine with the latter class of jig. The six spindles are driven by gears from the motor on the sliding head, and the boring bars are held in floating chucks, each bar having a single-pointed



(*Wm. Asquith, Ltd., Halifax*)

FIG. 58. DUPLEX FOUR-SPINDLE BORING MACHINE FOR AUTOMOBILE CYLINDERS

cutter and a floating type reamer. The vertical traverse of the head is obtained from a screw. The quick traverse of the head during non-cutting periods comes from the auxiliary reversible motor seen on the top of the column, and the fine cutting feed is derived from the spindle driving mechanism. Two clamps hold the



(*Wm. Asquith, Ltd.*)

FIG. 59. SIX-SPINDLE AUTOMOBILE CYLINDER BORING AND REAMING MACHINE, WITH JIG

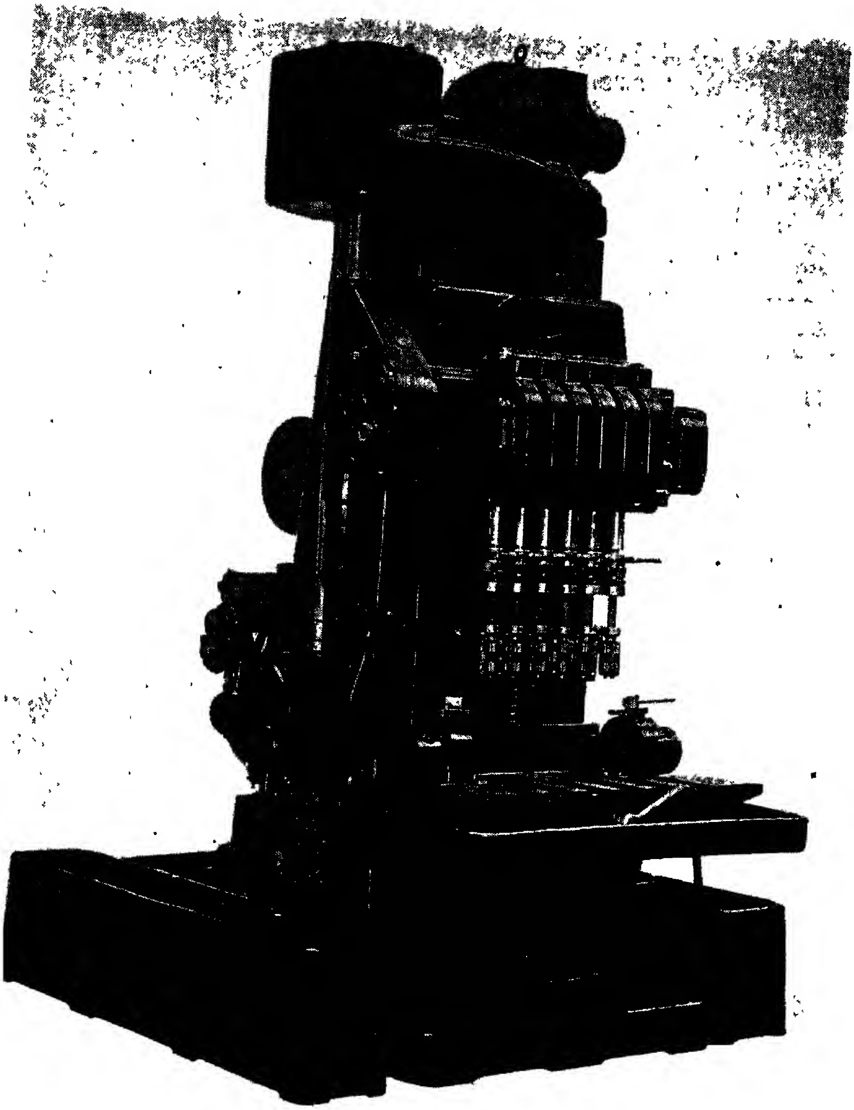


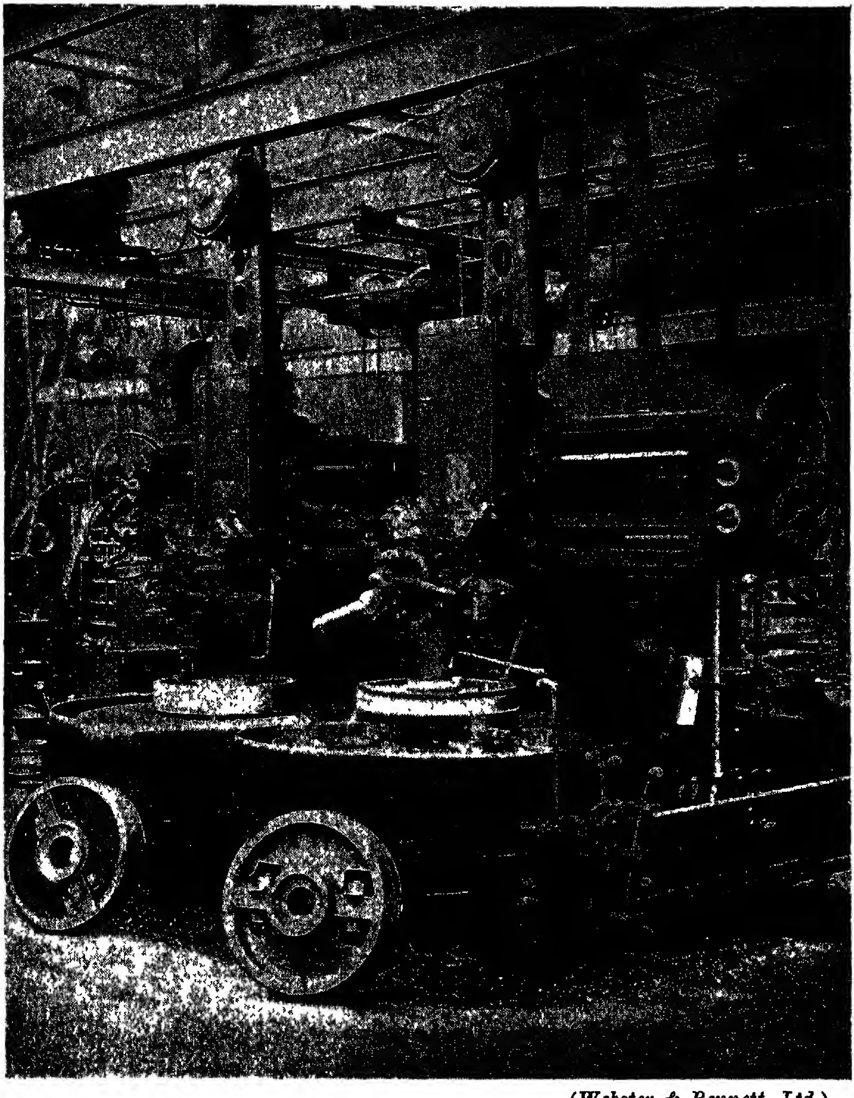
FIG. 60. SIX-SPINDLE ASQUITH HONING MACHINE FOR FINISHING BORED CYLINDERS

cylinder in position. The duplex four-spindle head machine in Fig. 58 deals with two cylinder blocks, and the spindles are different to those in the previous machine, being of the snout type. They are carried out in stiff tubes, with conical bushings to take up wear. When desired, the heads can be easily replaced by others carrying a different number of spindles to suit other cylinders.

Although not a boring process, it is interesting to note the method now largely adopted to finish the bores of the automobile cylinders, instead of the planetary grinding process hitherto commonly adopted. A revolving and reciprocating hone is employed, this comprising a set of cylinders of abrasive material mounted in a circle so as to expand against the bored hole. After a certain number of reciprocations the head rises out of the way. Paraffin is used as a lubricant, and the result is a very highly-finished interior. A machine may have a single spindle, the hone being lowered into each bore in succession, or all the bores may be finished at once, in a multiple type. This is the form shown by Fig. 60 (Asquith). The spindles are driven by worm gear, and a timing device is incorporated to stop the reciprocations after any desired number. On the completion of the operation, the attendant depresses a handle, and the table is automatically lowered by power to a bottom position. The holding fixture is devised so as to permit of tilting the block forward to inspect the bores as well as for removal and reloading.

BORING AND TURNING MILLS

These are not restricted to boring any more than are the various kinds of lathes, automatic screw machines, and automatic turning machines. But frequently they engage on boring alone as a preparatory



(*Webster & Bennett, Ltd.*)

FIG. 61. 42 IN. DUPLEX MILL BORING AND TURNING TRAM-GEAR FORGINGS

stage to mounting a piece of work in a chuck or fixture for further operations. On the duplex-spindle mills (see Fig. 61) an article may be bored in one chuck and transferred to the other, or on to a centring fixture for turning, facing, grooving, etc. Boring is accomplished with the same tool-slide or bar which serves for other operations, or, in a few instances, a supplementary bar is carried on the cross-rail and driven independently to give an increased rate of cutting for a hole while turning is proceeding at a slower rate. Special mills are built to handle wheel tyres for railway service, and have a powerful central ram descending with the boring tool. To speed up production, the machines are fitted with quick-acting crane arrangements to remove a bored tyre and put in a fresh one, and one type of mill has a chuck which automatically grips the tyre directly the spindle starts rotating. The great advantage of the boring mill for all work that can be chucked or clamped to the table is, ease of placing and setting on the horizontal surface, and clear view of the tools and their action.

The " size " of the mill in Fig. 61 is that of the chuck diameter. The number of speeds is twelve, and there are six feeds. Conveniently placed levers effect the changes, the feeds being vertical, horizontal, or angular, and these can be tripped automatically at any point. The rapid power traverses for giving quick adjustments to the tools save much time in setting. It will be noted that the cumbersome weights and chains formerly used to balance the turrets are eliminated in favour of compensating springs, enclosed in the circular casings at the top of the picture.

SECTION XVII

GRINDING AND GRINDING MACHINES

BY

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SECTION XVII

GRINDING AND GRINDING MACHINES

THE very great development that has taken place during recent years in grinding practice can be traced to improvements in the manufacture of grinding wheels, and the abrasive materials from which they are made. The motor-car and cycle industry, with its great demand for very accurate hardened steel components, is largely responsible for the recent improvements in grinding machine design.

It can be said that nearly every department of the modern engineering workshop is taking advantage of the obvious superiority of this type of machine tool, over all others, for many classes of work. It can also be said that a machine shop is incomplete without its correct proportion of grinding machines.

The grinding machine is unlikely to displace other types of machine tools purely as a metal removing machine, but it can undoubtedly do a great deal more in that direction than is generally realized. For finishing operations the grinder is superior to any other class of machine, both as regards finish, accuracy, and time taken, not only on repetition work, but in many cases on single jobs. The great ease with which the grinder can be set-up ready for work makes it an ideal machine for all classes of work, except roughing.

The idea that grinding is only suitable and economical when dealing with hardened steel work requiring great accuracy, is erroneously held by many engineers, who cannot have had the opportunity of seeing the large variety of general work these machines will

actually produce. It certainly has the advantage over all other types of machines of being able to deal with hardened steelwork with the same degree of accuracy, and quite as rapidly, as it can deal with the softer metals.

Emery was used for many years as the abrasive medium, and the word grinding meaning wearing away to a powder by friction, might have been a suitable term to apply to that class of work, but the modern grinder is essentially a cutting machine. An abrasive wheel of moderate size will have some millions of cutting edges operating per minute, but if the metal it removes from the work is examined under the microscope the particles will be found to be similar in shape to the swarf removed from a lathe.

It can be safely said that the introduction of grinding machines and grinding processes into any engineering workshop will lead to an improvement in the general accuracy and finish of the work produced, together with a reduction in costs.

ABRASIVE MATERIALS

For a very considerable period of time emery was exclusively used in the manufacture of abrasive wheels for grinding purposes. It is mined in Asia Minor, Greece, Spain, and other parts of the world and is a grey mineral rock consisting of an aggregation of corundum and iron oxides, or crystals of aluminium oxide imbedded in a matrix of iron oxide. Although hard and tough, it is unsuitable for precision grinding on account of the large percentage of iron it contains, and also owing to its varying quality. It is now only used on rough and heavy work, such as fettling castings and trimming parts of steel work.

Another natural, but more satisfactory abrasive is *corundum* (Al_2O_3). This mineral is found in India,

Canada, South Africa, and the United States of America, and is, chemically, aluminium oxide, or imperfectly crystallized ruby or sapphire. This material is more suitable for accurate work than emery because of its greater hardness, and its comparative freedom from impurities.

Two artificial abrasives are in general use, *carborundum* and corundum. The former has been in use the longest period, and is obtained by fusing coke, white sand, salt, and sawdust in an electric furnace at a temperature of about 7000° F. for a period of about 36 hr. The coke is used to supply the carbon, and the sand the silicon. The sawdust keeps the mixture porous and allows the impurities to escape in gaseous form, and the salt assists in the chemical combination of the silica and carbon. The crystals obtained by this method are crushed and subjected to the action of dilute sulphuric acid to remove or dissolve the impurities remaining, and silicon carbide (Si C) is obtained.

Artificial corundum or alumina is produced by smelting bauxite, which is a yellow clay found in Southern France, America, Canada, and many other parts of the world, in an electric furnace. Its chemical composition (Al_3O_2) is similar to the natural corundum, and it is artificial to the extent of being crystallized in the electric furnace instead of in the earth by natural means.

THE MANUFACTURE OF ABRASIVE WHEELS

Grinding wheels are manufactured by mixing crushed and prepared grit particles with a suitable bonding material, and then treating the mixture in such a manner as to produce a grinding wheel that will be satisfactory for a given purpose.

For engineering purposes four different processes are employed ; these are known as vitrified, silicate, rubber, and elastic, and refer in particular to the

bonding material used, and also to the method of preparation.

VITRIFIED PROCESS

The vitrified process of manufacturing wheels is mainly adopted because it has been found to give the most satisfactory results on the majority of grinding operations. A very open texture is obtained by this method, and the wheel has very free cutting properties.

In this process the grit particles of proper grain size are placed with the correct proportion of feltspar clay and fluxes, in a mixing machine, water is added, and the mixing proceeds until a uniform consistency is obtained. The mixture is then run into suitable moulds and allowed partly to dry, after which a more complete drying takes place in a heated room. The rough wheels are then turned to shape and again dried, and are finally placed in a form of pottery kiln and subjected to a white heat, at which temperature the clay vitrifies. Considerable skill and experience is required to carry out this operation, and the time taken will depend upon the size and weight of the wheel. The actual vitrifying may take from three to fourteen days, and about seven days are required for the furnace to cool down.

This class of wheel can be identified by its reddish colour, and the clear ringing sound obtained when it is tapped. About 80 per cent of the wheels in general use for engineering purposes are manufactured by this method.

THE SILICATE PROCESS

The silicate process of wheel manufacture is one in which the principal bonding material is silicate of soda or waterglass. The mixture of bonding material and grit particles is firmly pressed into suitable iron moulds,

dried, and then baked at a comparatively low temperature until a chemical reaction takes place and hardens the bond. The time taken to produce a silicate wheel is much less than by the vitrified process. As a greater proportion of bond is required for this method than is the case with a similar grade vitrified wheel, the structure is less open and consequently less porous, and the bond is not so hard. The baking takes place in a specially built oven from which all gases of combustion are excluded, the temperature is maintained at 500° F., and the time taken varies from 20 to 80 hrs. according to size and weight.

Silicate wheels can be recognized by their light-grey colour, they have a tensile strength of about 2000 lb. per sq. in.

RUBBER WHEELS

The bonding material chiefly used in the manufacture of what are termed vulcanized wheels, is rubber. The rubber is treated with sulphur, and the abrasive grit particles are spread between the halves of a sheet of this prepared material, which is then folded upon itself, and passed through a calender roll until the required thickness is obtained. The wheels are then formed from the sheet by means of a special machine, which heats and subjects them to pressure until the vulcanizing is complete.

A wheel made by this process is considerably stronger than either the vitrified or silicate wheel, and is much closer in texture.

ELASTIC WHEELS

The principal ingredient used in the bond of elastic wheels is shellac. This material is mixed with the correct proportion of grit particles in a steam-heated mixing machine, producing a granular mixture of grit

particles, each particle being coated with the bond. Thin wheels are obtained by pressing the mixture into heated moulds of the same size as the required wheel, and firmly rolling by means of a steel roller. Heavier wheels are obtained in the same manner, but hydraulic pressure is used to press the mixture into the moulds. In both cases the wheels after being formed are placed in sand and baked at a temperature of about 300° F. Shellac wheels will be found to be nearly black in colour.

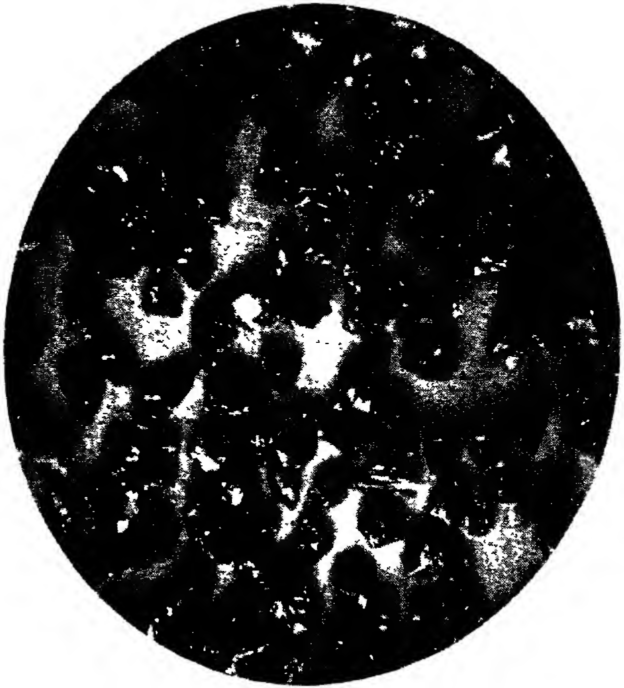
ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT BONDED WHEELS

Wheels made by the vitrified process are porous and free cutting, they are uniform in texture, without hard and soft spots, and are not affected by change of temperature, acids, or water, and are used for general purposes up to about 30 in. in diameter.

The chief disadvantage is the difficulty of manufacturing wheels of large diameter. The time taken in vitrifying is comparatively long, and large wheels are liable to crack in the kiln. The great heat necessary for this process appears to weaken the grit particles, with the result that uniformity is difficult to obtain.

Silicate wheels have been successfully manufactured up to 60 in. in diameter, and the time required is much less than by the previously mentioned process. The abrasive particles are not held so firmly together, with the result that they have a milder and less harsh cutting action, and consequently can be used to greater advantage on tools and cutters requiring a keen cutting edge such as reamers and milling cutters. In wet grinding the soda in the bond tends to give a better finish to the work.

Wheels made with either rubber or shellac as the bonding material have the greatest strength and flexibility, and are specially useful where a very thin



(*Norton Company, Worcester, Mass., U.S.A.*)

FIG. 1. MICROGRAPH OF CRYSTOLON ABRASIVE
(Silicon carbide)

FIG. 2. MICROGRAPH OF ALUNDUM
(Aluminium oxide)

wheel is necessary; they can be safely run in water, but should not be used with oil or caustic soda because oil will tend to soften the bonding material, and caustic soda will disintegrate the wheel structure. These wheels are capable of producing a very high degree of finish, and are frequently used for finishing the surface of chilled iron, cast iron, and steel rolls, and hardened steel cams. Very thin wheels are used for slotting purposes, and for cutting off tubes and pipes; also for slitting sheets of metal, particularly when difficulty is experienced in holding the work firmly.

NAMES GIVEN TO ABRASIVE WHEELS

The trade-mark names given to the silicon carbide class of wheel include "Carborundum," "Carbosolite," "Corex," "Crystolon," "Electrolon," "Gresolite," and "Sterbon." They are now manufactured in Austria, England, Germany, Sweden, Switzerland, the United States, and possibly other countries.

The names given to the aluminium oxide class of wheel made from natural or artificial corundum include "Aloxite," "Alundum," "Boro-carbone," "Borolon," "Carbo," "Corem," "Corolex," "Electrit," "Geddite," "Rebite," "Rex," and "Rexite." The great majority of the wheels manufactured at the present day by reputable manufacturers are satisfactory in all respects if they are used according to the instructions of the makers. Figs. 1 and 2 show micrographs of "Crystolon" and "Alundum."

USE OF ABRASIVES

The abrasives in general use for engineering purposes can be divided into two categories, aluminium oxide and silicon carbide. The natural and artificial corundums appear to be of about equal merit, and are chiefly used for grinding metal of high tensile strength. Silicon

carbide, owing to its comparative brittleness, is more suitable for grinding metals of low tensile strength. The following will show the usual practice—

Metals	Abrasive	Metals	Abrasive
Alloy steels Carbon steels Bronze hard Malleable iron Wrought iron	Ground with Aluminium oxide abrasive.	Aluminium Brass Bronze soft Cast iron Copper	Ground with Silicon carbide abrasive.

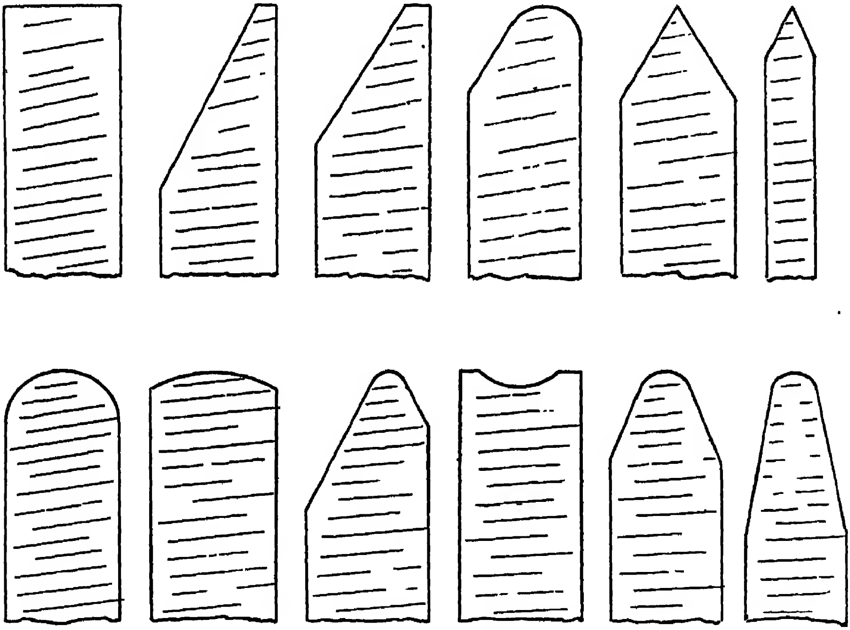


Fig. 3. Profiles of Wheel Faces

SHAPES OF GRINDING WHEELS

The standard shapes given to plain disc grinding wheels are shown in Fig. 3. All of these can usually be supplied by the manufacturers or their agents from stock.

In addition to plain disc wheels, a very great number

of other shapes are required for the different types of grinders, and for different classes of work. The diameter and width of a wheel will mainly depend upon the size and power of the machine on which it is to be used.

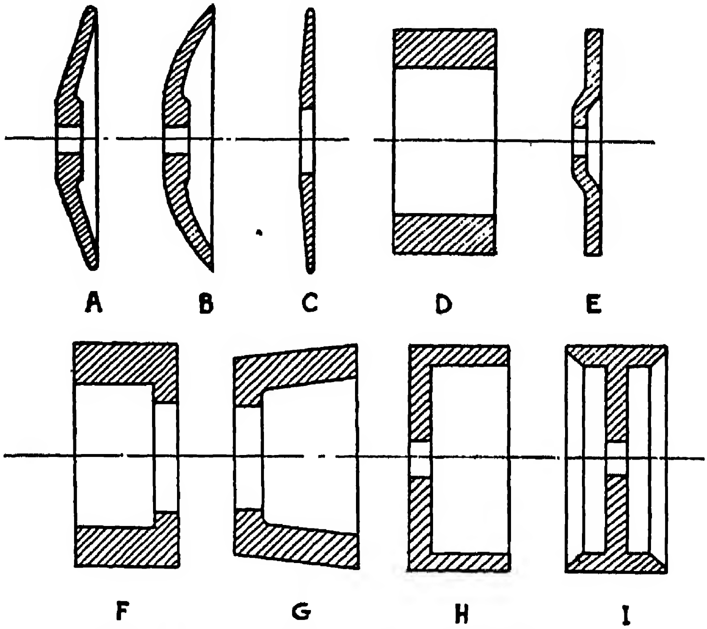


FIG. 3A. SECTIONS OF ABRASIVE WHEELS

Sections of those wheels in general use are given in Fig. 3A, and are named as follows—

A—Straight saucer wheel
B—Curved saucer wheel
C—Flat saucer wheel
D—Cylinder wheel
E—Flat-faced wheel
F—Cup wheel
G—Tapered cup wheel
H—Cup wheel
I—Tee-shaped cup wheel

The saucer wheels shown at *A*, *B*, *C*, are extensively used on tool and cutter grinders for the purpose of grinding and sharpening milling cutters and reamers; *D* is largely used on vertical spindle surface grinders;

E is secured to the end of a horizontal machine spindle, instead of in the middle, and is intended for work requiring to be ground to a shoulder, such as a small piston rod with the piston in position ; *F* is required for some types of tool and cutter grinders ; The form of wheel *H* is also used on tool and cutter grinders ; *I* is a special wheel required for the " Cincinnati " machines.

GRAIN OF WHEELS

The approximate size of the abrasive grit particles used in the composition of a grinding wheel indicates its coarseness or fineness, and is termed the grain of the wheel. After the abrasive material has been crushed, it is sifted and graded according to the number of holes in the sieve through which it has passed. Thus, when a 40-grain wheel is indicated, it means that the grits have passed through a sieve having 40 holes to the linear inch. In a straight-grain wheel all the grit particles are approximately the same size, whereas, in a combination wheel the grit sizes are varied, and on some classes of work a combination wheel cuts fast, leaves a good finish, and retains its cutting properties longer than the straight-grain wheel. When a 24–80 combination wheel is referred to, it means that a proportion of all sizes between 24 and 80 has been used.

Grits for precision grinding vary from 20 to 80, while for other classes of work the numbers run from 10 to 200, after which it is termed flour.

GRADE OF WHEELS

The grade of a wheel is determined by the power of the grit particles to resist disintegration when under cutting pressure. It is obvious that the greater the proportion of bonding material for a given quantity

of grit particles, the harder the wheel must be. When the grits are easily broken away from the bond, the wheel is termed soft, and when the wheel retains the grit particles for a much longer period, it is termed hard.

The various grades between very soft and very hard are obtained by varying the amount of bonding material. Manufacturers of abrasive wheels usually indicate the hardness of a vitrified wheel by means of a letter of the alphabet, E being soft and U being hard. The wheels in general use vary from G to S, but H to O will be found to cover most of the work met with in the engineering workshop.

Silicate wheels and elastic wheels have their degree of hardness indicated as shown in the following table, but this is not universal, and manufacturers should be consulted before wheels are ordered.

GRADES OF ABRASIVE WHEELS

Degree of Hardness	Vitrified Process	Silicate Process	Elastic Process	Rubber Process
Soft . . .	E			
	F			
	G	G or ½	E ½	
	H	H or ¾	E ¾	
Medium soft .	I	I or 1	E 1	
	J	J or 1½	E 1½	
	K	K or 2	E 2	
	L	L or 2½	E 2½	
Medium . .	M	M or 3	E 3	
	N	N or 3½	E 3½	
	O	O or 4	E 4	
	P	P or 4½	E 4½	
Medium hard .	Q	Q or 5	E 5	R 7
	R	R or 6	E 6	
	S	S or 7	E 7	R 8
	T			
Hard . . .	U			R 9

PLAIN CYLINDRICAL GRINDING

Before commencing to grind any external cylindrical piece of work it is necessary to take into consideration the following factors—

1. The class of wheel to be used.
2. The surface speed of the work.
3. The travel of the wheel or work.
4. Support for the work.
5. Speed of abrasive wheel.
6. Type of centres to be used.
7. Depth of cut.
8. Water supply.

The most difficult of these factors to determine is the wheel selection. Before it is possible to determine the class of abrasive, the bond, and the grade and grain of the wheel, it is necessary to consider the physical properties of hardness, toughness, and ductility of the metal to be ground. Those metals having a comparatively high tensile strength can be ground to the best advantage with crystalline aluminium abrasives, and metals of low tensile strength, with silicon carbide abrasives. Hard and brittle metals require a fine-grain wheel, and ductile metals allow the use of coarse-grain wheels.

The quality of finish desired and the amount of metal to be removed will have a great influence on the grain size of the wheel. When the work requires to have a large amount of metal removed, coarse-grain wheels, or coarse-grain combinations can be used in order to facilitate the rapid removal of the metal. The quality and accuracy and hardness of the metal will, however, limit the grit size.

When the quality of finish is of no great importance, coarse-grain wheels can be used, but for precision work only a small range of grit sizes will be found suitable.

It is often possible to use a coarse-grain wheel on a

heavy rigid machine and obtain good results, whereas the same wheel on a light machine would be quite unsatisfactory.

The size and shape of the wheel will be determined by the size of the machine being used and the nature of the work. In all cases large diameter wheels are more economical than small ones, but the diameter and width are limited by the size and power of the machine. For plain grinding on external work where the wheel traverses to give the feed or travel, a disc wheel is most frequently used.

SPEED OF WORK

The surface speed of the work will depend upon the relative size of the grinding wheel and the work, the class of material being ground, and the quality of finish desired. A speed varying between 25 ft. and 60 ft. per min. will be found to cover most of the requirements for precision grinding, but cast iron is often ground at speed up to 120 ft. per min. With grinding, more than with any other class of work, experience will help the operator to determine the most suitable surface speed ; and it is a simple matter to alter the speed while grinding is taking place. If the work speed is too low, local overheating may take place, and should the speed be too high, vibration may be set up and chatter marks appear on the surface of the work.

Should the face of the wheel glaze quickly an increase of work speed may be tried, but if the wheel wear away rapidly a decrease in work speed might improve matters.

If an alteration in work speed will not give the results desired, a more suitably graded wheel should be used.

TRAVEL OF WHEEL OR WORK

The majority of grinding machines are designed so that the wheel travels in order to obtain the feed

longitudinal with the work. In some machines, however, the wheel moves in order to obtain the necessary movement for cutting. In both cases the rate of movement is governed by the width of the wheel. For taking roughing cuts the movement of the wheel is approximately two-thirds the width of the wheel per revolution of the work, and unless the travel exceeds half the width of the wheel per revolution of the work, the wheel will have a tendency to wear convex on its face. For finishing, the travel of the wheel will have to be reduced. In some cases an improved finish can be obtained by increasing the work speed, allowing the travel to remain constant, and reducing the depth of cut.

SUPPORTING WORK

Nearly all work, except short, stiff jobs, requires support in addition to that given by the machine centres, because, unless it is sufficiently supported, chatter marks are liable to appear on the surface. Chatter marks will be found to consist of a number of small flats, and are mainly due to vibrations set up either in the work or the machine. When the marks appear in a straight line they are probably due to work vibration, and when they assume a helical form they are more likely to have been caused by vibration in the wheel spindle or machine itself.

To overcome the trouble of vibrations on the work surface, it is usual to fit steady rests, and, if possible, one should be used for each length of six diameters. Steady rests can always be used to advantage, and the more rests used on a piece of work the deeper the cut, and the greater the travel of the wheel. When ample steady rests are used on a piece of work and vibration marks still appear, then a change in work speed can be tried; if that is not successful, attention should be

given to the running parts of the machine, by adjusting belts, and testing for rigidity.

STEADY RESTS

A universal steady rest suitable for all classes of work, more particularly for long slender shafts, is shown in

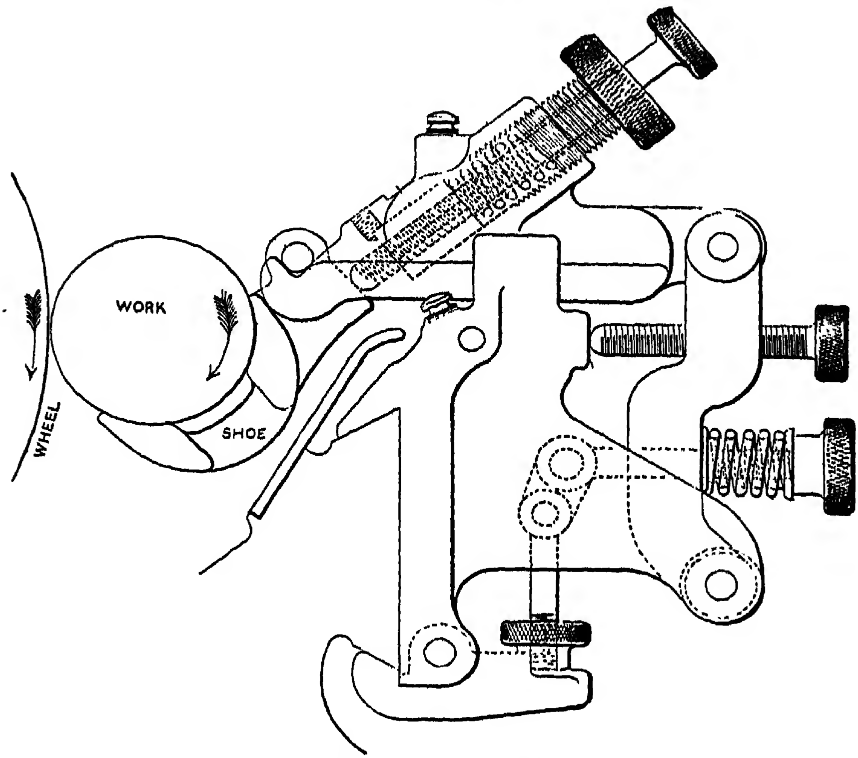


FIG. 4. UNIVERSAL STEADY REST

Fig. 4. The solid shoe shown in position is made of bronze, and each piece of work requires a shoe to suit its diameter. The various adjustments can be plainly seen in the illustration. The rest is particularly adapted for work requiring a fine degree of accuracy, and for use when grinding splined shafts.

Plain back rests are simple in construction, and can be used to advantage whenever they are likely to increase the steadiness of the work. The rest shown in Fig. 4A is one manufactured by Messrs. Brown & Sharpe; wooden shoes are usually fitted because they can be more readily adjusted to the diameter of the work than

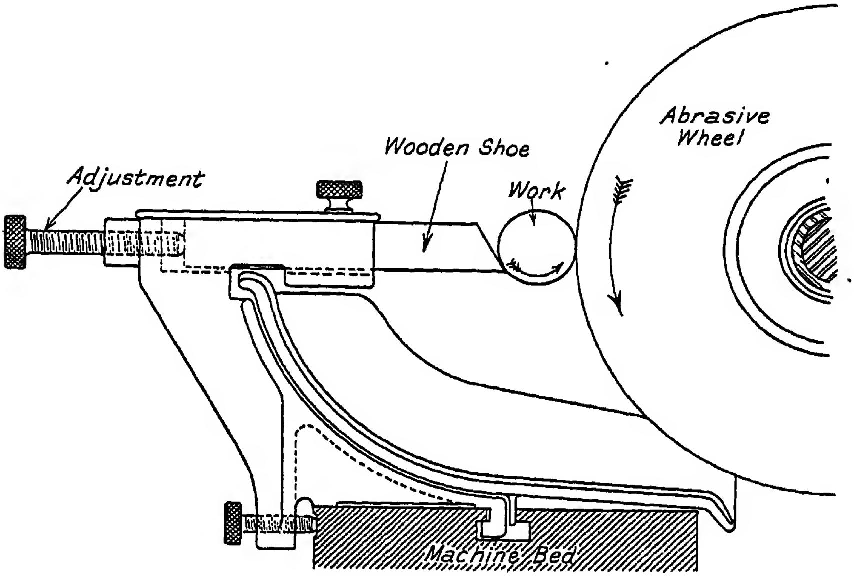


FIG. 4A. BACK STEADY REST

metal ones. Soft metal shoes, made to fit various diameters, should be used when a large number of pieces of the same diameter have to be ground. The shape of these metal shoes can be varied to suit the work, and will be dependent upon the judgment of the operator.

SPEED OF ABRASIVE WHEELS

The peripheral speed of abrasive wheels for external cylindrical grinding varies from 5500 ft. per min. to

6000 ft. per min. The manufacturers of abrasive wheels invariably indicate the most suitable speeds for each wheel, and this speed should be adhered to as closely as possible. The maximum recommended speed should never be exceeded, and should be only slightly reduced when absolutely necessary.

It will be noted that as a wheel wears away the peripheral speed is reduced. On some machines it is possible to increase the speed in revolutions per minute, and this should be done as necessary in order to obtain the correct peripheral speed.

It is of great importance that the speed of the grinding wheel should remain constant during the cutting operation; an excessive depth of cut, or travel of the wheel, tends to reduce its speed, and will result in very unsatisfactory work.

The drive of the machine should be sufficiently powerful to prevent slowing of the wheel under all reasonable conditions. The speed of a correctly graded wheel running at constant speed has no direct influence on the output of a machine, but in all cases it is economical to maintain the speed in order that soft and free cutting wheels can be used to take comparatively heavy cuts without excessive wear.

MACHINE CENTRES

It is only possible to grind work accurately when the machine is fitted with correctly designed centres giving sufficient area to support the work. The centres must always run perfectly true, and should be re-ground in the machine at intervals or when a specially accurate piece of work is required. It is a complete waste of time to attempt to grind any job on badly formed machine or work centres.

The centres in the work are quite as important as the machine centre, and in all cases should be proportional

to the size and weight of the work, truly conical, and of the same angle as the machine centres.

Several different types of centres are in general use, mainly in connection with the diameter of the work being ground. Those made from high-speed steel are more satisfactory and durable than when made from plain carbon steel.

DEPTH OF CUT

The output of a grinding machine depends far more on the travel of the work or wheel than on the depth of cut. A machine with a fast table or wheel-head travel with a comparatively light cut will give a greater output than a slow-running machine taking a heavier cut, and will have the advantage of not stressing the work to the same extent.

When a considerable amount of metal has to be removed from the work, cuts of from 0·001 in. to 0·003 in. can be taken, while for finishing the depth of cut would vary from 0·00025 to 0·0005.

WATER SUPPLY

The operation of grinding metals always results in the generation of heat, and unless this heat is conducted away as quickly as possible, the work is liable to become distorted. The use of a plentiful supply of water on *all* metals prevents the work from becoming overheated, carries away the dust and metal particles, and improves the quality of the work surface.

An excessive amount of water may possibly make a mess, but it will not do any harm to the work or wheel. Plain water is satisfactory, but it tends to rust the work and machine parts. A suitable solution can be made by adding 1 lb. of soda and 1 pt. of soluble oil to 10 gal. of water. The amount of solution to be used will depend upon the diameter and width of wheel, the surface speed

of the work, and the physical properties of the metal being ground; a 12 in. wheel of 2 in. face requires about 6 gal. per min.

Aluminium is frequently ground with a mixture consisting of ten parts of paraffin to one of lard oil. When grinding copper (a very difficult matter when a fine finish is required) it is very desirable to fix a fine gauze strainer to the water outlet in order to remove the metal particles and prevent them being pumped on to the wheel.

WHEELS FOR CYLINDRICAL GRINDING

The following wheels will be found suitable for grinding the metals mentioned—

Metal	Light Plain Grinders	Heavy Plain Grinders
Mild steel	Alundum M 60	Alundum L comb 24
Case-hardened steel	Alundum K 60	Alundum K comb 24
High-speed steel	Alundum K 38 to 60	Alundum K 38 to 46
Cast iron and soft brass	Crystolon K 46	Crystolon K 36
Gunmetal and hard Bronze	Alundum L 60	Alundum L comb 24
Copper	Crystolon K 100	Crystolon J 100
Aluminium	Crystolon J 46	Crystolon J 36

PLAIN CYLINDRICAL GRINDING MACHINES

This type of grinding machine is mainly intended for external cylindrical work and form grinding, more particularly from a manufacturing point of view. In comparing the plain grinder with the universal type, it can be said that for a given size the former is heavier and much simpler in construction than the latter. Plain machines are usually mounted with larger diameter and wider wheels, and the feeds are coarser than in the case of universal machines. The headstock, wheel-stand, and tailstock of the plain machine cannot

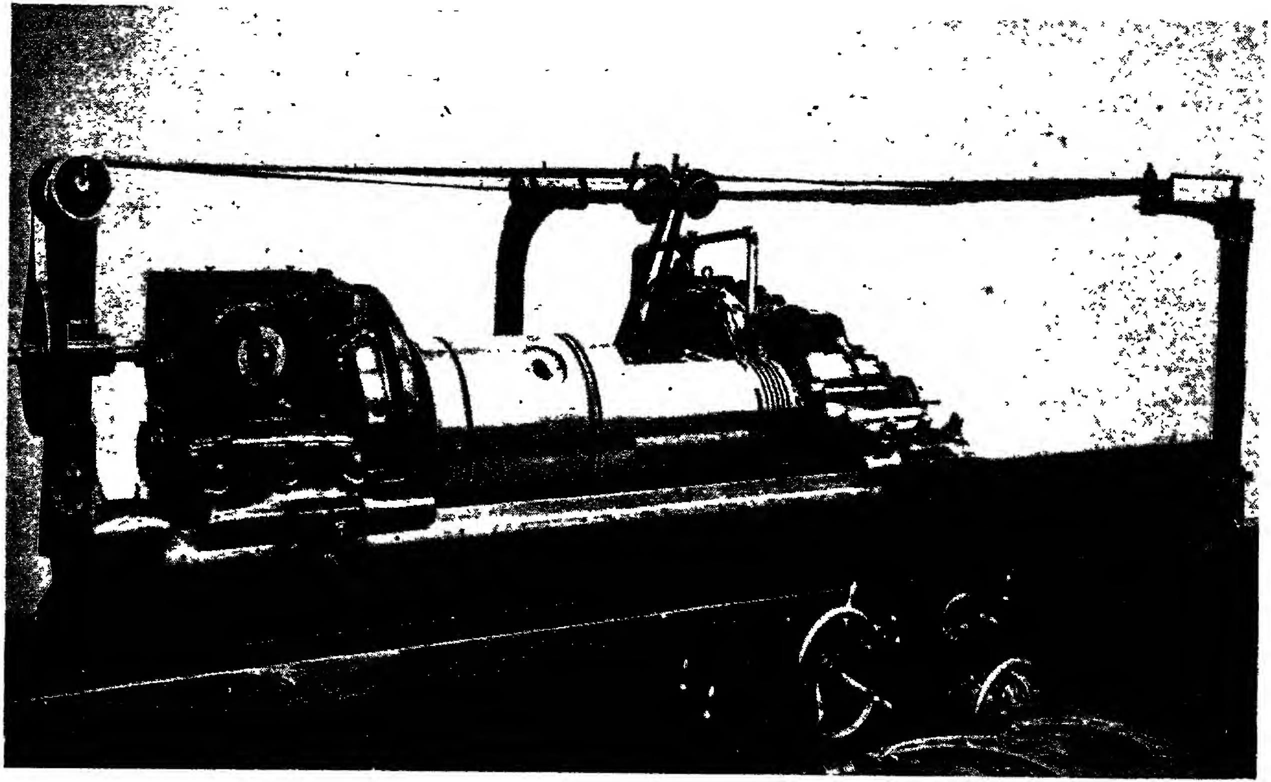


Fig. 5. Plain Grinding Machine Operating on a Large Piston

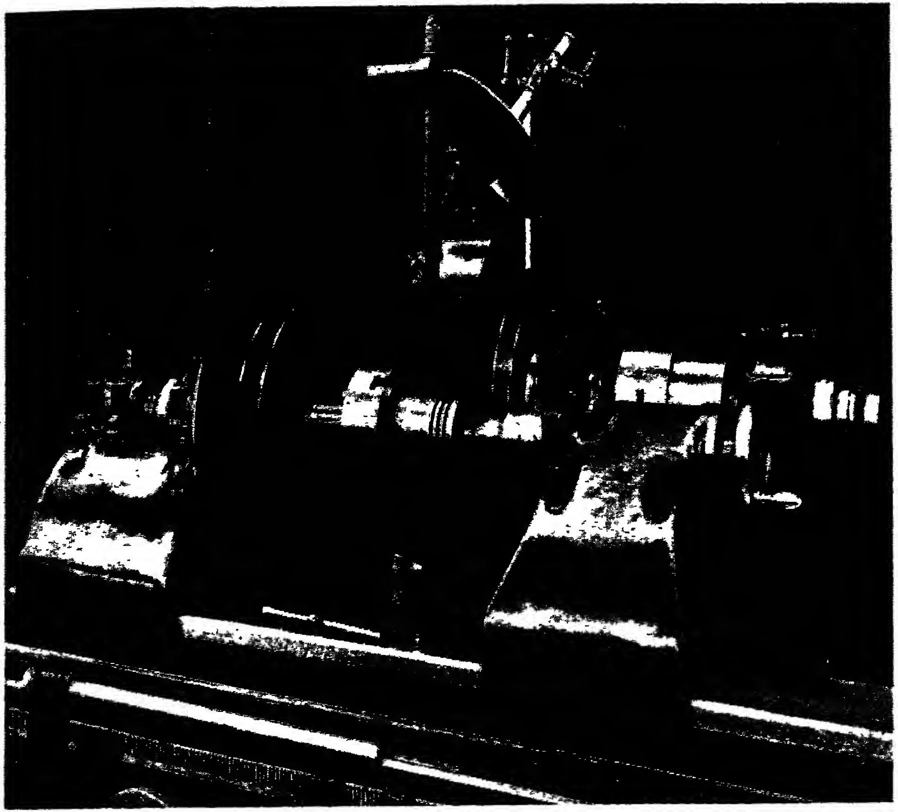


Fig. 6. Plain Grinder Grinding a Small Piston

be swivelled, but the table in many cases can be moved sufficient to enable slight tapers to be ground.

There is probably no class of machine tool in general use whose value is more dependent upon rigidity of construction than the grinding machine. Surface finish and accuracy are the principal qualities of its product, and the presence of vibration is sufficient to destroy either of these. There are few machines employed on such a fine class of work that have more unfavourable conditions to contend with. The rapidly revolving wheel and the abrupt reversal of the table or wheel at both ends of their traverse, conduce to vibration, which is further increased by the cutting action of the wheel.

A good idea of the great development that has taken place in the construction of grinding machines will be obtained when it is realized that machines are at present being manufactured of such a size as to be capable of dealing with work up to 50 in. in diameter and 26 ft. in length.

A plain grinding machine with a capacity of 30 in. by 120 in. is shown in operation grinding a large piston, in Fig. 5. This machine, which is manufactured by The Churchill Machine Tool Co., Manchester, carries a 26 in. by 3 in. abrasive wheel. It is provided with two wheel speeds, sixteen work speeds, and ten table speeds. The main drive is by means of a 30 h.p. motor and the work drive by a 10 h.p. motor.

A smaller type of plain grinder by the same makers is shown in Fig. 6. This machine is specially intended for handling all classes of comparatively short work. In the illustration the machine is engaged in grinding small internal combustion engine pistons.

WIDE WHEEL AND FORM GRINDING

Machines capable of grinding without lateral feed have many advantages over those using narrow

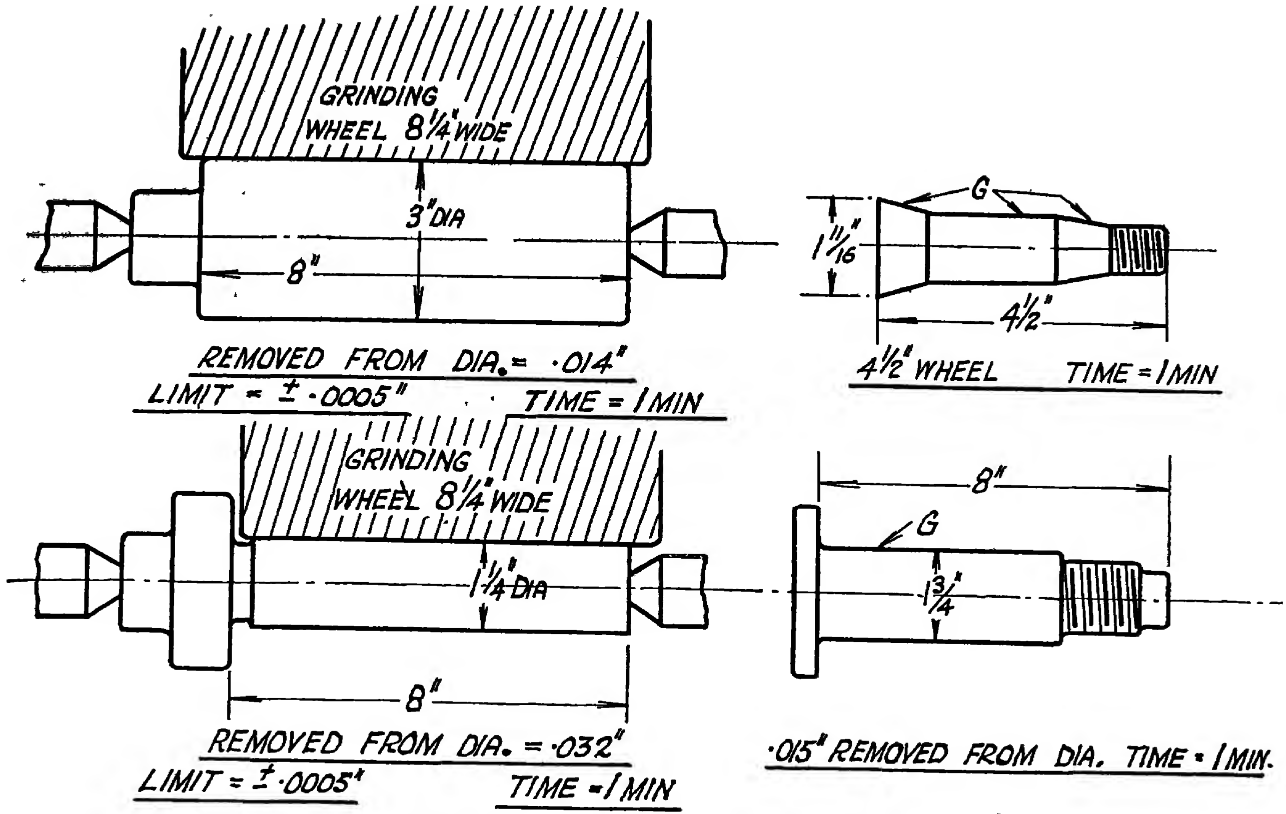


Fig. 7. Examples of Form Grinding

grinding wheels, the chief of which is the shortening of the time required for a given job. Machines for this purpose are constructed by The Churchill Machine

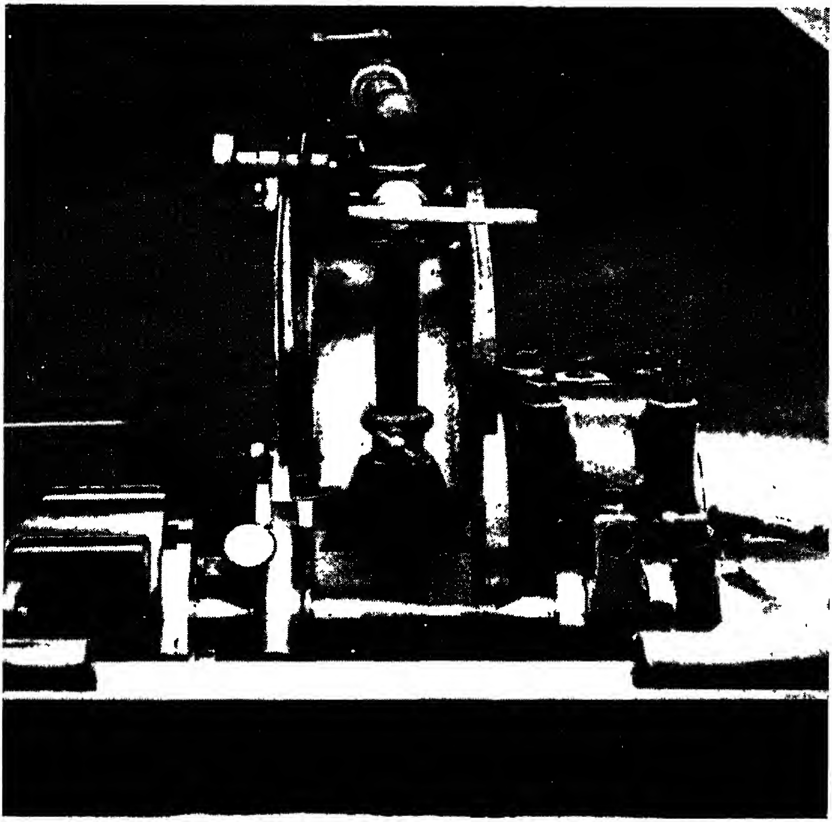


FIG. 8. DUPLEX WHEEL OPERATION

Tool Co., and the examples shown in Fig. 7 have been carried out on their machine and give an idea of the time taken to carry out work of this character. Specially heavy spindles capable of carrying wide wheels are fitted, and the wheels may be either plain or of the desired profile. It is also possible to

fit the spindle with double wheels of two diameters so that two different diameters of work may be ground simultaneously by the straight-in feed method. Another important feature of these machines, which is of great value when grinding by this method is an oscillating motion which can be given to the table when desired.

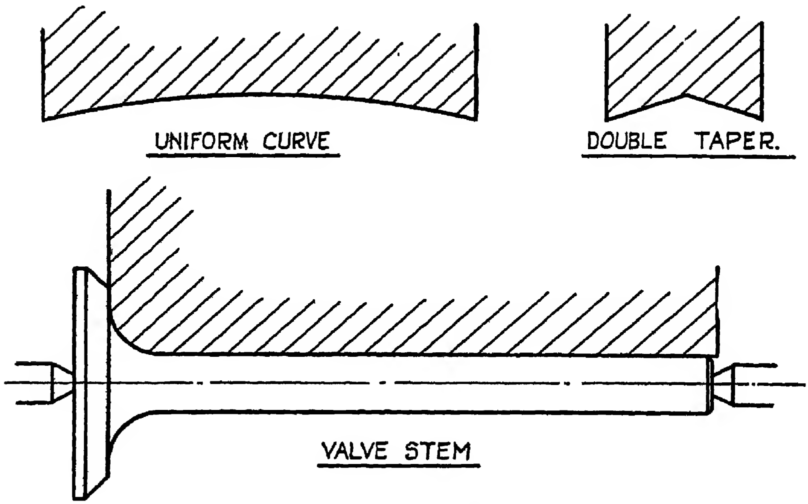


Fig. 9. Form Grinding Wheels

The effect of this motion is to maintain the running accuracy of the wheel face and to give a higher finish to the work than is obtainable from a wheel fed directly on to the work without oscillating mechanism.

Stationary automatic feed can also be provided for use in conjunction with the oscillating motion.

A duplex wheel operation is shown in Fig. 8. The work, consisting of a light car stub axle, has its two diameters ground simultaneously with a straight-in feed.

WIDTH OF WHEELS

The width of a grinding wheel is at present limited by manufactory difficulties, and the cost of wide wheels

is considerable. Abrasive wheels up to 10 in. in width are frequently used, but broad wheels require a very heavy slide on account of the bearing pressures being much greater than when narrow wheels are used. The power required to drive the wheel is also greater, and would be equivalent to that necessary for a number of narrow wheels whose total width is equal to the width of the broad wheel.

Wheels intended for form grinding, such as shown in Fig. 9, will have different diameters at various points on the periphery, and as the cutting speed must consequently vary, it follows that a limit can be reached in the depth of the form. In all cases of form grinding sharp corners and undercuts must be avoided, and fillets used whenever possible. The work to be form ground should either be stiff and rigid or sufficiently supported to reduce vibration to a minimum.

SURFACE GRINDING AND SURFACE GRINDING MACHINES

The surface grinding machine is intended for the purpose of producing flat surfaces, within precision limits, on pieces of work, and may be carried out either direct from the rough forging or casting, or from a previously machined surface.

A considerable number of components which at one time were machined on planers, shapers, and millers, are now successfully dealt with on one of the various types of surface grinding machines.

Surface grinding machines are no longer considered as machine tools to be used exclusively on work requiring an accurate high-class finish, but are at the present time largely used in production work of a heavy character without previous machining. The time taken to finish a piece of work will compare favourably with any other method of production, while

on suitable work it is frequently the most economical process.

With the modern machine it is possible to grind to within the limits of 0·0005 in. without the slightest difficulty.

TYPES OF SURFACE GRINDERS

Grinding machines for surface work are constructed according to many different designs, each particular type being manufactured in several different sizes with the object of dealing with particular classes of work in the most convenient and efficient manner.

The following are the principal types of surface grinders in general use: 1. Horizontal machines. 2. Open side grinders. 3 Face grinders. 4. Vertical spindle machines. 5. Horizontal spindle machines. 6. Plano-grinders.

1. The horizontal type of surface grinder is provided with a reciprocating table on to which the work is secured. The abrasive wheel is mounted on a horizontal spindle, the wheel used is a plain disc, and the periphery is used for grinding.

The work table is automatically traversed at right angles to the direction of table travel in order to obtain the feed, and the wheel-head, together with the wheel spindle and wheel, is moved vertically to give the depth of cut.

Machines of this type are used to a very great extent in the tool-room and for all classes of components requiring accurate plain surfaces.

2. Open side grinding machines are constructed in sizes capable of grinding work of considerable length and width, but having one side of the machine open as in the case of the open side planing machine, it will accommodate work of awkward or unequal shape.

3. Face grinding machines provided with horizontal

spindles are intended for heavy work, and carry ring or segmented wheels. The abrasive wheel is generally large enough to cover the work face to be ground, and thus a cut is complete at one traverse of the table.

Machines of this type have a table travel of from 15 ft. to 30 ft. per min., and surfaces are finished very rapidly with a reasonable degree of accuracy.

4. Vertical spindle machines are being used to a large extent; they are arranged to carry cup, ring, or segmented wheels large enough to cover the surface of the work, and may have reciprocating or rotating tables. Grinders of this type, when provided with an ample supply of cooling medium, are extremely efficient in all suitable classes of production work.

5. The horizontal spindle type of machines are particularly useful for grinding such work as piston rings, collars, washers, and valves. They are provided with rotary tables, often magnetic, and a plain disc wheel is used. The wheel is fed across the surface of the work by means of an acceleration mechanism, and by this means a concentric radial finish is obtained on the surface of the work.

6. The plano-grinder, as the name implies, is constructed somewhat similar in design to the planing machine. The wheel spindle may be vertical, in which case a ring or cup wheel is used for grinding, or it may be horizontal, and mounted with one or more plain disc wheels. The former method is most desirable for work of large area requiring a cut all on one plane, and the latter when the work has projections or requires grinding on narrow surfaces on more than one level.

WHEELS FOR SURFACE GRINDING

It is often more difficult to select a suitable wheel for surface grinding than it is for plain cylindrical work. Cup and ring wheels must be of soft grade, not only on

account of the large area of work covered, but also on account of the rapid loading up of the wheel if the metal particles are not washed away from between the face of the wheel and the surface of the work.

It is always very desirable that a list of all the wheels found suitable for grinding various metals should be kept for reference. The following list will indicate the class of wheel, with the grade and grain, for use on the various metals mentioned.

WHEELS FOR SURFACE GRINDING

Metal	Plain Disc Wheels		Cup and Ring Wheels
Carbon steel, soft .	Aluminium oxide .	I to J 24 to 30	L to M 24 to 30
Carbon steel, hard'ed	Aluminium oxide .	G to I 20 to 30	J to K 36 to 46
Cast iron . .	Silicon carbide .	G to J 24 to 30	L to M 30 to 46
Brass . . .	Silicon carbide .	G to J 20 to 30	K to L 30 to 46
Aluminium, cast .	Silicon carbide	¾ E to I E 24 to 30	2 E to 3 E 30 to 36
Malleable cast iron .	Silicon carbide .	G to H 16 to 30	G to H 16 to 24

WHEEL SPEEDS

The peripheral speeds of grinding wheels for surface grinding are generally lower than for cylindrical work, and vary according to circumstances from 3000 to 5000 ft. per min. Cup and ring wheels are usually run at a speed of about 4000 ft. per min., and plain disc wheels at 5000 ft. per min. It should be noted that cup and ring wheels have a constant cutting speed irrespective of any wear down of the wheel, whereas in the case of the disc wheel the peripheral speed is reduced as the wheel wears.

SPEED AND FEED OF WORK

The table speed of many of the smaller surface grinders is constant, only one speed being provided. This arrangement simplifies the construction and gives very satisfactory results. Some of the larger machines are designed for more than one speed, and usually

speeds of from 25 ft. to 50 ft. per min. will cover all requirements.

The output of any machine will not only depend upon the work speed but also on the traverse of the wheel or work. When the periphery of a disc wheel is used for cutting, the feed given is from three-quarters to nearly the full width of the wheel for roughing, provided in all cases that the machine has sufficient power to maintain the peripheral speed of the wheel while it is cutting. For finishing the feed must be reduced, and the amount will depend mainly upon the quality of finish desired and the degree of accuracy necessary.

DEPTH OF CUT

The depth of cut has very little influence on the output of a modern grinding machine; it is much better to have several light cuts than a few heavy ones. The actual cutting depth varies from 0·00025 in. for finishing high-class precision work to a maximum of 0·005 of an inch for the heaviest grinding on powerful machines fitted with segmented wheels.

WATER SUPPLY

Many of the small horizontal grinding machines used in the tool-room are constantly working without the use of a cooling medium. In this case a soft grade disc wheel is generally used, and the amount of metal removed is small, and the absence of water is of little consequence.

One of the difficulties connected with surface grinding, particularly with cup and ring wheels, is the rapid generation of heat owing to the large area of contact.

Whenever possible, a plentiful supply of water should be used for cooling purposes. On heavy vertical spindle machines as much as 40 gal. per min. is used on the inside and outside of ring wheels, but this is partly

done with the object of washing away the metal particles from between the face of the wheel and the work.

When grinding, work of thin section warping will often occur, and is due to the rapid generation of heat in one part of the work and the inability to allow for free and equal expansion. This unequal expansion causes the work to become convex, and on cooling to become concave.

When work is found to heat up quickly on a machine having a constant wheel and work speed, the difficulty can often be overcome by reducing the depth of cut and increasing the feed, and by that means distributing the heat over a greater area. Should the result still be unsatisfactory, then a wheel of softer grade and different grain should be tried.

It is usual to add sufficient sal-soda to the water to prevent the surface of the work or machine from rusting, and the further addition of a small quantity of soluble cutting oil will tend to stop the deposit of soda.

METHOD OF HOLDING WORK

The most suitable method of holding iron and steel work is by means of the magnetic chuck, of which a great variety are on the market. This class of chuck is quickly and easily operated, and enables the work to be ground more accurately than would be the case if it was held by any other method.

Non-magnetic metals, such as brass and aluminium, can be held in a machine vice or ordinary type of chuck, or by means of dogs directly on to the machine table. In the case of production work a special fixture can be designed for holding the work.

SURFACE GRINDING MACHINES

A small horizontal surface grinding machine is illustrated in Fig. 10. This machine is manufactured

by The Churchill Machine Tool Co., Manchester, and is intended for rapid and accurate grinding of flat surfaces up to 24 in. in length by 6½ in. wide. The

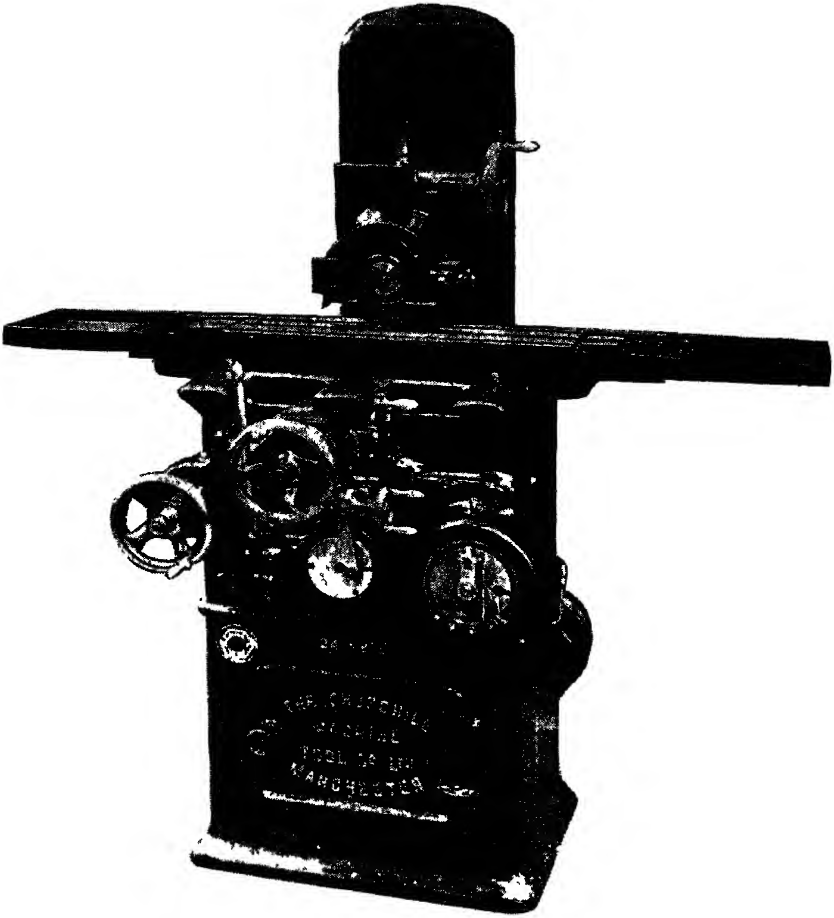


Fig. 10. Horizontal Surface Grinder

wheel spindle is hardened and ground, the rear end running in ball-bearings.

The spindle head carrying the wheel spindle and wheel is raised or lowered into position by means of a

hand-wheel which is graduated for thousandths of an inch, and is provided with a dead stop.

The table travels on Vee and flat ways, and its reversal is controlled by dogs mounted on a slotted disc in the front of the bed. The cross movement of the table is self-acting in either direction, the feed acting

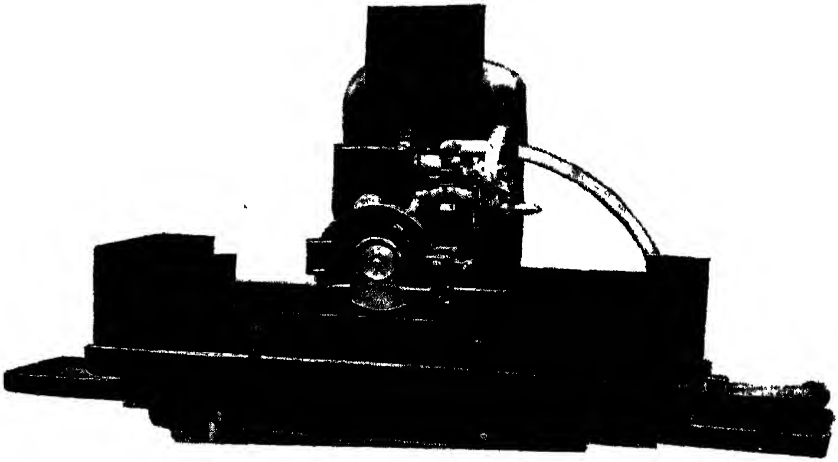


FIG. 11. SURFACE GRINDER ARRANGED FOR WET GRINDING

at each reversal of the table. It can be set to feed automatical at any amount from 0·015 in. to 0·19 in., and may be automatically tripped at any desired point. A fine adjustment to the cross feed can be used when desired for such work as grinding precision gap gauges.

When wet grinding is necessary an equipment consisting of a pump, tank, and piping is fitted, and in order to protect the operator and keep the water on the work a guard as shown in Fig 11 is fitted to the top of the table.

VERTICAL SPINDLE MACHINES

The increasing use of surface grinding machines is due to a very large extent to the evolution of those

types of machines using ring or segmented grinding wheels, which render it possible to rough grind a piece of work without preliminary machining, and also to attain the greatest possible degree of accuracy and smoothness on the surface of the work. Machines of this type cover with their abrasive wheels the entire width of the surface to be ground, and obviate the necessity of any movement of the work other than the longitudinal reciprocating movement of the table.

The grinder illustrated in Fig. 12 is manufactured by Messrs. Schuchardt & Schütte, for whom the agents are The Dowding Machine Tool Co., Bush House, Aldwych. These machines are manufactured in three sizes, the largest having a table working surface of 1500 mm. by 3800 mm. The abrasive wheel carried by this machine is 300 mm. in diameter by 35 mm. in width. The spindle head has twenty-four variations in vertical feed varying from 0·0025 mm. to 0·06 mm., and the table is provided with four speeds of 1·15, 1·45, 1·8, and 2·3 m. per min.

A section through the main spindle is shown in Fig. 13. It will be seen that the main bearing is tapered and located close to the grinding wheel. To remove any backlash the solid bearing can be adjusted from outside by means of a threaded ring. Lubrication of the bearing is effected through continuous automatic circulation of oil through the oil chambers by means of spiral oil grooves cut in the spindle. The pressure due to grinding is taken up by a ball thrust bearing close to the grinding wheel. Another ball thrust is provided in the top bearing box where a radial ball-bearing is located to take up the side pull of the belt. Pressure springs are fitted into the protecting bushing of the upper spindle end to balance the weight of the spindle and to prevent the taper from binding.

The wheel-head slide carrying the grinding spindle

moves on long prismatic ways with prismatic gibs, and is balanced by counter-weight. After loosening a

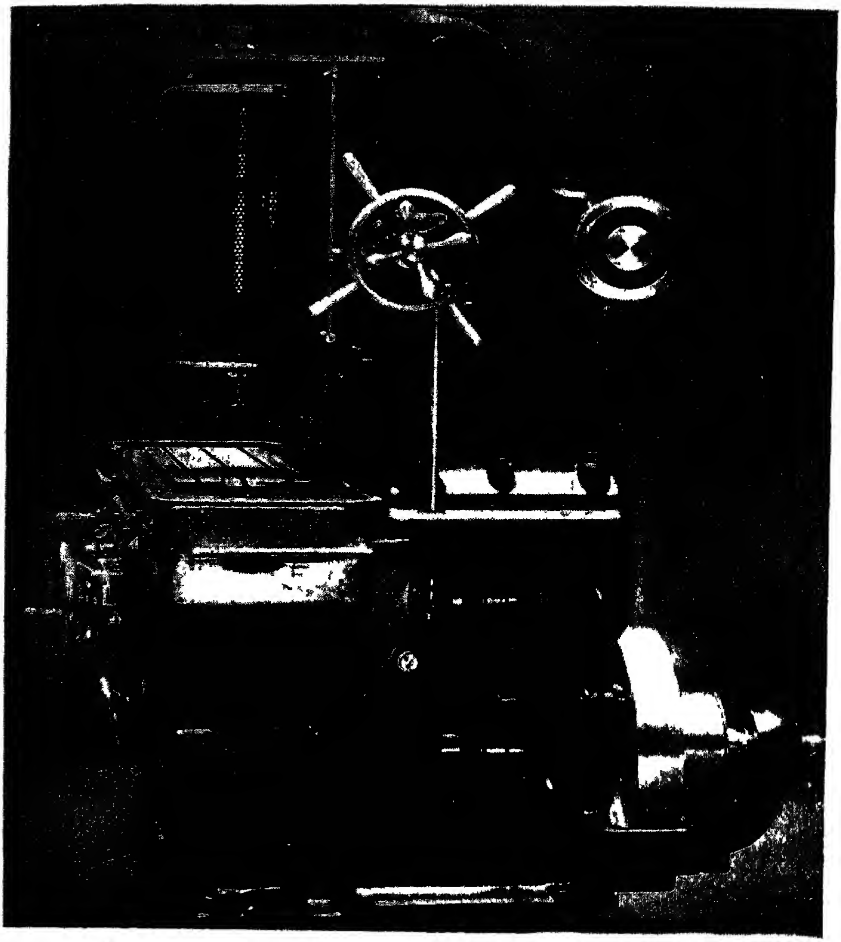


FIG. 12. AUTOMATIC VERTICAL SPINDLE GRINDING MACHINE

binding screw, the slide can be raised or lowered rapidly through rack and pinion by means of a hand-wheel located at the side of the machine. This facilitates the approximate adjustment of the wheel-head

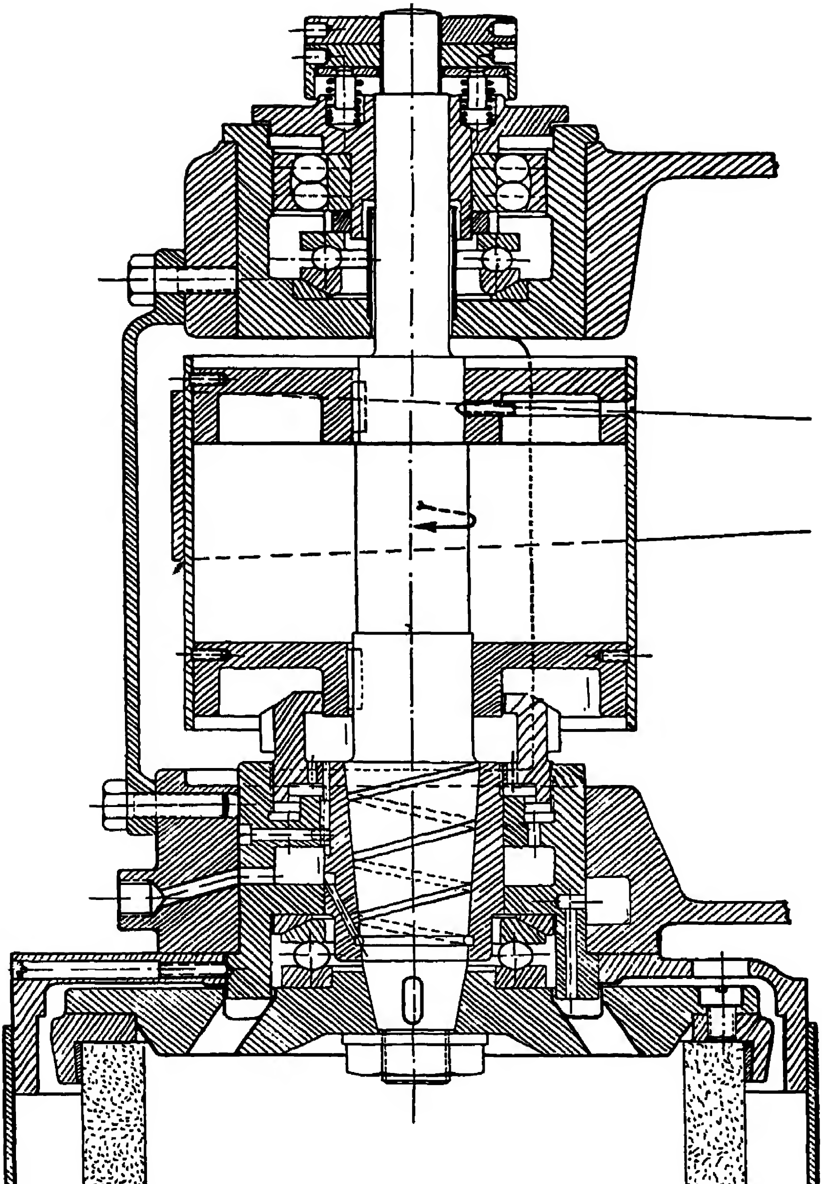


FIG. 13. SECTION THROUGH SPINDLE AND BEARINGS
Of Vertical Spindle Grinding Machine

slide before the automatic feed is engaged. Provision is made for a vertically adjustable clamping collar and index.

The machines have single pulley drive with a friction clutch worked by foot. The wheel spindle is driven from the main shaft by a belt running over idler pulleys. The bracket carrying these pulleys is adjustable for tightening the belt. Ball-bearings are used for the friction clutch, main shaft, and guide pulleys. The drive to the main shaft of the machine can be taken from the shop shafting or direct from an electric motor.

The machine is equipped either with a segmental chuck taking eight abrasive segments or with a ring wheel. The use of a segmental chuck is to be recommended when grinding with a table loaded to its full capacity or where large unbroken surfaces have to be ground. In the case of narrow surfaces with large gaps or spacings abrasive ring wheels are to be preferred.

"LUMSDEN" ROTARY TABLE-SURFACE GRINDER

A modern rotary table-surface grinder manufactured by The Lumsden Machine Co., Gateshead, is illustrated in Fig. 14. It is largely used for grinding textile machinery parts in quantity, and for this purpose a magnetic chuck is employed. When dealing with textile frame castings the chuck is removed and the work or fixtures are bolted direct on to the tee-slotted table, which has a diameter of 6 ft. The maximum depth admitted between the table and the 3 ft. diameter abrasive wheel is 18 in.

The segmental grinding wheel is mounted on a flanged spindle which runs in roller bearings in a cylindrical ram. This ram is carried by a cross-arm mounted at one side of a stiff cylindrical column, while the other end is steadied by a planer type standard. This cross-arm

is balanced by a guided counter-weight, and when set may be securely clamped by bolts to the column and standard. Both standards are rigidly bolted down to

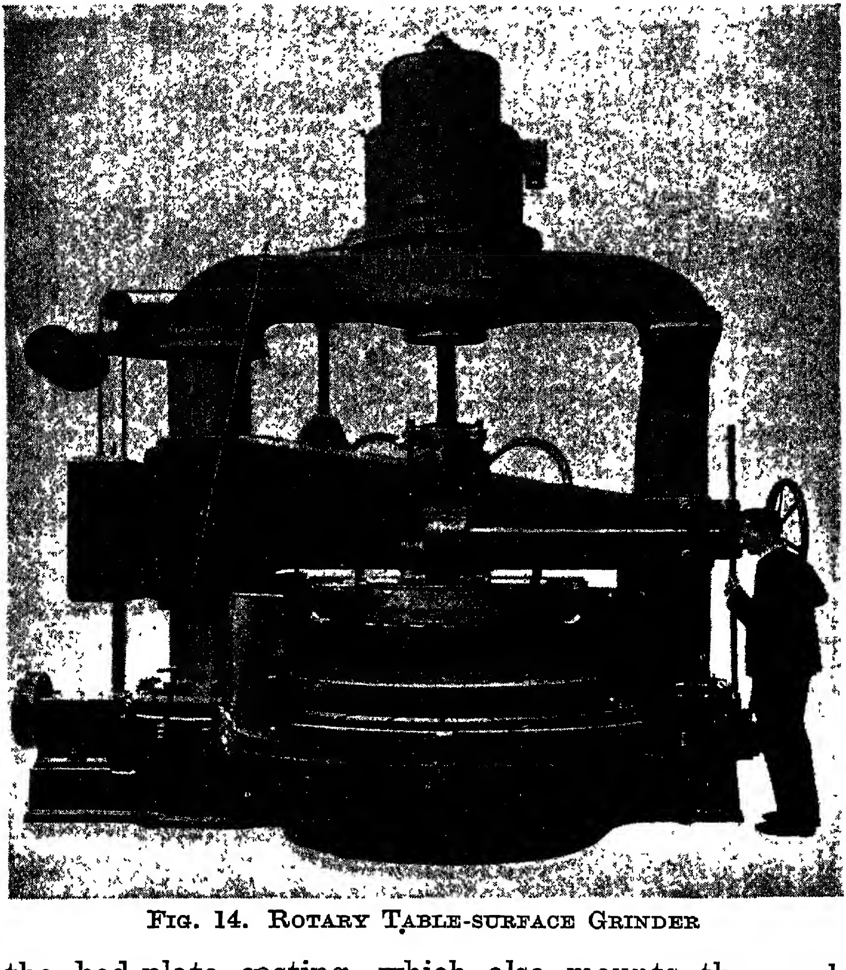


FIG. 14. ROTARY TABLE-SURFACE GRINDER

the bed-plate casting, which also mounts the work table.

A power-elevating motion is provided to advance or withdraw the wheel arm quickly. This is operated

through gearing, vertical screw, and nut by means of a handle on the inclined rod on the left. Both hand and automatic feeds are provided on the cylindrical ram. Hand adjustment is through the hand-wheel on the right-hand side through horizontal shaft and gearing. The automatic feeds are taken from a horizontal shaft running through the gear-box on the left to lever and feed mechanism on the right-hand side, then through a vertical shaft to gears at the end of the horizontal shaft referred to for the hand traverse.

A 60 h.p. motor is used for driving, and runs at 500 rev. per min. It is mounted centrally on the top cross-brace piece for the two columns. The grinding wheel spindle is driven through a splined shaft. The rotary motion of the table is obtained from a pulley on the motor shaft, by belt over the jockey pulleys to the pulley on the gear-box, carried on an extension to the bed-plate at the left, and thence to the table gearing. Two changes of speed are provided by the gear-box, which is actuated by a friction clutch, giving the table 4 and 6½ rev. per min. The grinding wheel is provided with water by a large capacity centrifugal pump at the rear along with the settling tanks. The approximate weight of the machine is 16 tons.

INTERNAL GRINDING

Internal grinding operations can be carried out on the Universal grinder, the tool and cutter grinder, or by means of the special horizontal or vertical internal grinders. Grinding is the most satisfactory method of finishing the bore of ring gauges, milling cutters, gears, and small cylinders, more particularly when parts have been heat-treated. When components are made from manganese steel, nickel chromium steel, or many of the new alloy steels, it is easier to obtain a high-class finish

together with great accuracy by means of the grinding machine than by any other method.

Heat-treated parts are very liable to distortion, and this can only be remedied by grinding. All work requiring a perfectly concentric bore with straight parallel sides, in order to secure perfect alignment when assembled, should be finished by internal grinding.

A large proportion of the holes drilled or bored in the modern shop are finished with some form of reamer, and while this is a quick and satisfactory method for certain classes of metals and on some types of work, it often presents difficulties on others. It is found that hard tough steel, close-grained cast iron, and most of the alloy steels soon dull the cutting edges of reamers, and a number of the softer metals and alloys are liable to drag badly when reamered. In all these examples grinding offers a satisfactory solution, and gives excellent results combined with great accuracy.

Many advantages are obtained by grinding the cylinders of small and medium size steam and internal combustion engines. It is found that hard and soft spots have little effect, if any, on the cutting properties of a correctly graded abrasive wheel. The steam or side ports do not affect the accuracy of the work, the amount of distortion due to holding and grinding the work is reduced to a minimum, and a high-quality finish can be obtained without the necessity of lapping.

TYPES OF INTERNAL GRINDING MACHINES

It is probable that during the last few years greater advances have been made in the design of internal grinding machines than in any other special type of machine tool, and machines are now constructed capable of dealing with work of very large size and very wide character.

Internal grinding machines can be broadly divided

FIG. 15. HEALD CYLINDER GRINDER FINISHING THE BORES IN MONOBLOCK CYLINDER CASTING

into two classes, one in which the work is held stationary, the grinding being done by a revolving abrasive which is given a planetary movement and at the same time is traversed backwards and forwards, and the other in which the work revolves and travels to and from a rotating abrasive wheel.

The former type of grinding machine may be constructed with either horizontal or vertical spindles, and

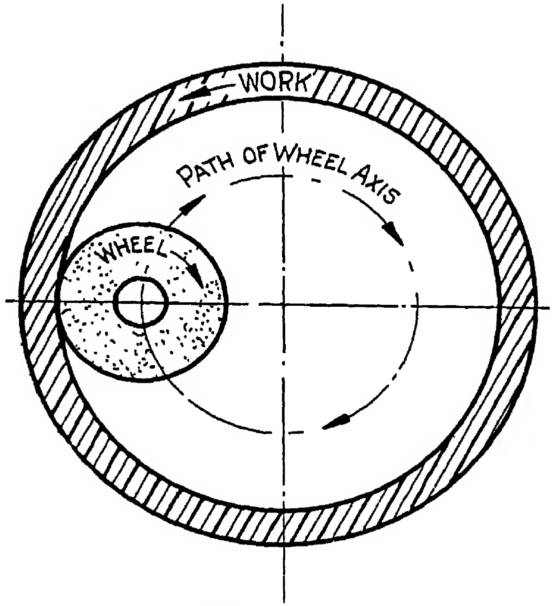


FIG. 16. PLANETARY MOVEMENT OF GRINDING WHEEL

are mainly intended for dealing with large and heavy work, such as steam and internal combustion engine cylinders, liners, and bushes, or work difficult or impossible to rotate. The latter type will be used for grinding smaller work, such as gears, ring gauges, collars, ball-bearing races, and jigs.

Machines constructed with planetary-moving wheel spindles are usually termed cylinder grinders, and the

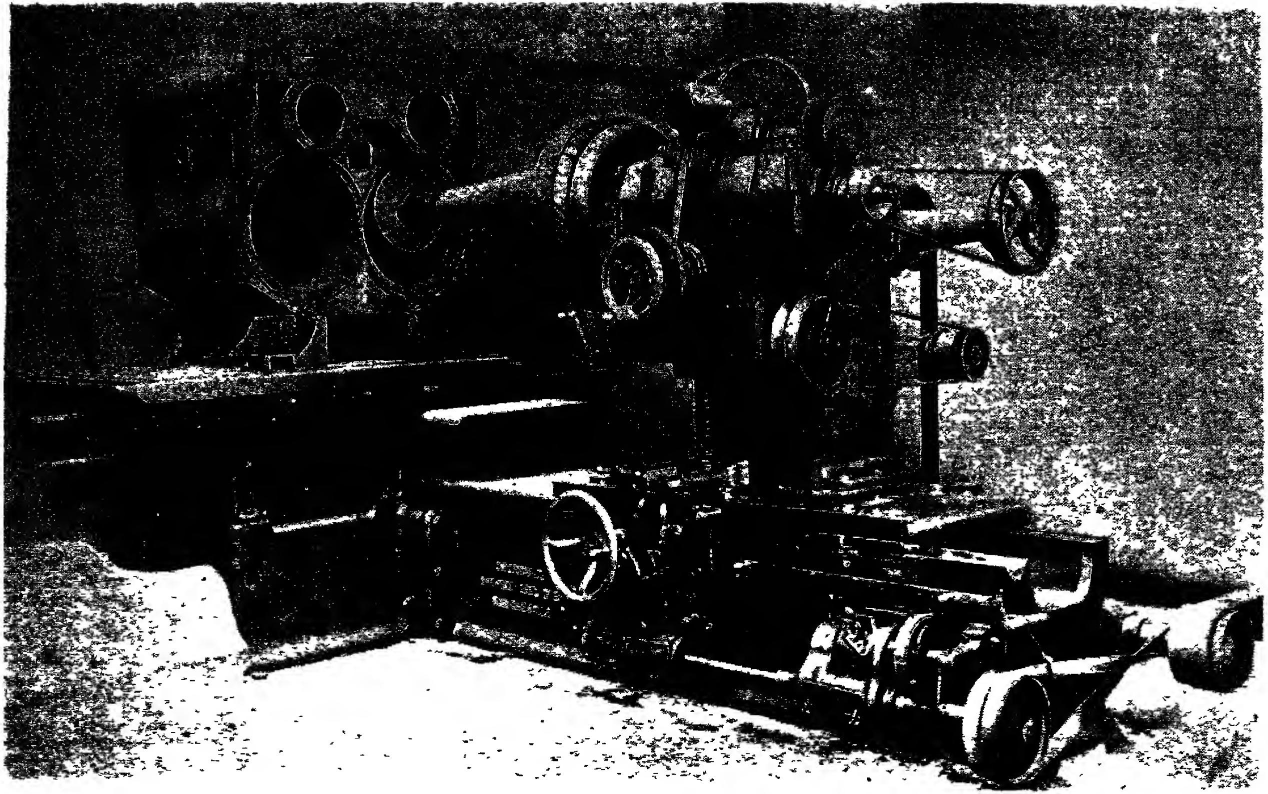


Fig. 17. Cylinder Grinder Operating on Locomotive Cylinder

axis of the wheel spindle will move in a path, as shown in Fig. 16. The depth of cut is obtained by feeding the wheel towards the work by means of an automatic mechanism.

A modern cylinder grinder, constructed by The Churchill Machine Tool Co., Manchester, is illustrated in Fig. 17. This machine, in addition to grinding cylinders, can be used for work which owing to its shape

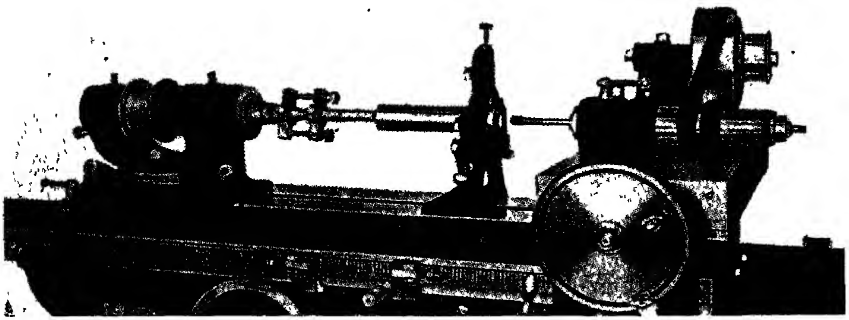


FIG. 18. GRINDING SPINDLES INTERNALLY

cannot be rotated in the ordinary type of grinding machine. This class of grinder is manufactured in five sizes, the largest having a capacity of 32 in. in diameter by 84 in. in length. The planetary adjustment in the smaller sizes is obtained through double eccentric spindles controlled through a differential motion, and in the larger sizes the adjustment is obtained direct on a slide mounted at right angles to the main spindle, and operated through a screw and differential motion.

The upper portion of a Churchill internal grinding machine suitable for small work is shown in Fig. 18. This illustrates the manner in which the grinding wheel spindle is driven, and also shows the method usually adopted for holding the free end of a piece of work requiring to be ground internally.

recesses or keyways require wider wheels, but when wide wheels of small diameter are used they have a tendency to cause overheating. Experience alone will determine the most suitable width.

WHEEL OR WORK TRAVEL

The amount of feed or travel of the work or wheel per revolution will be governed by the width of the wheel. On heavy, rigid, well-designed machines the travel can be nearly the full width of the wheel for roughing, but this will have to be reduced for finishing, if a good quality surface finish is required.

WATER SUPPLY

Many classes of tool-room and small general work are ground quite dry, but when great accuracy is necessary and a good-quality finish is required, it is usual to have a steady supply of soda water running in the work.

Cast iron, brass, and some of the bronze alloys are often ground dry, but for soft and hardened steels water is always used when possible.

ALLOWANCE FOR GRINDING

Although it is only possible to take a cut up to about 0·003 of an inch in depth, the coarse feeds obtainable on the modern grinder make it capable of removing a considerable amount of stock. The modern practice is to increase the grinding allowance, and give more work to the machine. When it is possible to set the work up quickly and accurately the grinding allowance can, of course, be reduced to a minimum.

The grinding allowance on a given job will depend mainly upon its diameter and the length of hole, the amount it is likely to run out of truth, and the class of material from which it is made.

The following allowances for various diameters will

be found to suit general requirements, and can be modified to suit the prevailing conditions—

GRINDING ALLOWANCES

Dia. of Hole	Allowance	Dia. of Hole	Allowance
In.	In.	In.	In.
½	0·005	4	0·011
1	0·006	5	0·013
2	0·009	6	0·014
3	0·010	9	0·018

These allowances are intended for holes of 1 in. in length, and an addition of 0·001 should be made for each additional inch in length. Thus, the allowance for a 6-in. hole 6 in. in length would be $0{\cdot}014 + (0{\cdot}001 \times 5) = 0{\cdot}019$ of an inch.

WHEELS FOR INTERNAL GRINDING

The following factors have to be considered when selecting an abrasive wheel for internal grinding: the class of material to be ground; the speed of the wheel spindle; rigidity of the wheel spindle and the machine; the diameter of the hole; quality of finish required; and whether the hole has recesses or keyways.

The class of material determines whether the abrasive material should be silicon carbide or aluminium oxide. When the machine spindle is rigid and the machine is heavy, the wheel can be softer in grade and coarser in grain, and a heavier cut can be taken, than would be the case on a light and less rigid machine.

As the size of the holes increases in diameter and length the wheels must be harder and of finer grain, in order that the cut may be finished before the diameter of the wheel has been reduced owing to wear.

For roughing, a soft wheel of coarse grain can be used; but when finishing it may be desirable to change the wheel and use one of slightly harder grade and finer grain.

When holes have recesses or keyways the wheel should be harder and of finer grain, because the sharp edges of the recesses have a tendency to tear out the grit particles.

The wheels given in the following list will often be found suitable for grinding the metals mentioned, and can be modified to suit the various conditions.

ABRASIVE WHEELS FOR INTERNAL GRINDING

Metals to be Ground	Class of Abrasive Grade and Grain
Aluminium, cast	Silicon carbide vitrified P 50
Brass, cast	Silicon carbide vitrified K 46
Bronze, cast	Aluminium oxide E 1½ to E 2½
Iron, cast	Silicon carbide vitrified P 46 to P 60
Steel alloy	Aluminium oxide vitrified K 46
Steel carbon, soft	Aluminium oxide vitrified L 36 to L 46
Steel carbon, hardened	Aluminium oxide vitrified K 46 to K 60
Cast iron cylinders	Silicon carbide vitrified I to K 30 to 46

SECTION XVIII

SLOTTING MACHINES AND SLOTTING

BY

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SECTION XVIII

SLOTTING MACHINES AND SLOTTING

THE modern slotter is a most economical tool when used for certain classes of work, and it is difficult to imagine how its place can be taken by any other class of machine tool. As the name implies, it is intended mainly for the purpose of cutting various kinds of slots, but it can also be used for such work as machining concave, circular, semi-circular, and convex surfaces, and for shaping internal and external forms or profiles.

The slotter is constructed on the same general principles as the Whitworth or the crank-driven shaping machine, the ram moving vertically instead of horizontally, and the tool cutting on the down stroke, usually at right angles to the work table.

METHOD OF DRIVING

The simplest method of reciprocating the ram is by means of a belt-driven shaft transmitting power to a disc crank through the medium of gearing, the length of stroke being varied by moving the crank pin to or from the centre of a "T" slot in the crank disc.

On some types of slotting machines the various cutting speeds are obtained by fitting a step cone pulley to the driving shaft. The modern method, however, is to mount a change gear-box in the trunk of the machine, and run the trains of gears by means of a constant speed shaft, either driven by a belt from a main or countershaft, or from a motor direct.

On heavy slotters requiring considerable power it is usual to have one motor for driving the ram, and a smaller motor for actuating the different table feeds.

A very satisfactory method of reciprocating the ram is by means of the Whitworth quick-return movement. This mechanism, when used in conjunction with a large diameter helical tooth driving wheel and a worm pinion, results in smooth and quiet running.

SIZES OF MACHINES

The size of a slotting machine is referred to in terms of length of stroke. Thus, a 10 in. machine would have a maximum stroke of 10 in., and the size of work machined would be less by an amount equal to the top and bottom clearance of the tool. Some manufacturers refer to their machines as 6/8 in. or 10/12 in. stroke machines, and in that case the lesser dimension is the depth of material which can be machined, and the larger dimension the maximum length of stroke.

TYPES OF MACHINES

Puncher Slotter. A puncher slotter manufactured by The Butler Machine Tool Co., Halifax, is illustrated in Fig. 1. This machine is capable of removing from 4 to 5 lb. of metal per min., and is intended for heavy work which has been forged, stamped, or sawn roughly to shape. With many heavy forgings the greatest amount of time is taken in drawing down or upsetting the metal so that the finished forging will require very little machining. The rough contour of a job can, as a rule, be easily and quickly obtained, and the puncher slotter can be used, not only to remove the surplus metal, but also to finish to shape, and the saving in time will more than compensate for the waste of metal. Locomotive crank webs can be slotted from

rectangular slabs to exact size in less time than by any other method.

The machine illustrated is driven by twin wheels having trunnions about three-fourths of their diameter, which work in bushed bearings fitted to each side of the trunk of the machine. The two driving wheels are

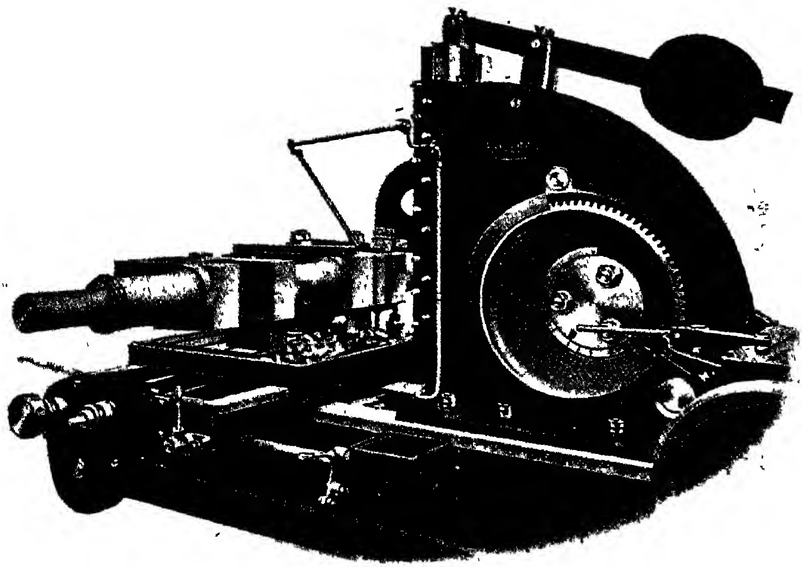


FIG. 1. HEAVY PATTERN PUNCHER SLOTTER

fitted with eccentrics which are made fast or loose with the wheels by means of three bolts, one of which passes through the machine, while the other two lock the front driving wheel and eccentric securely together. The driving is accomplished by a bronze die working in a slotted link, this die being carried on a hardened steel bush fitted in recesses between the two eccentrics and through this bush the long bolt passes.

The slotted link is of bell crank lever type, oscillating on a pivot, the driving slot being in the long end, and

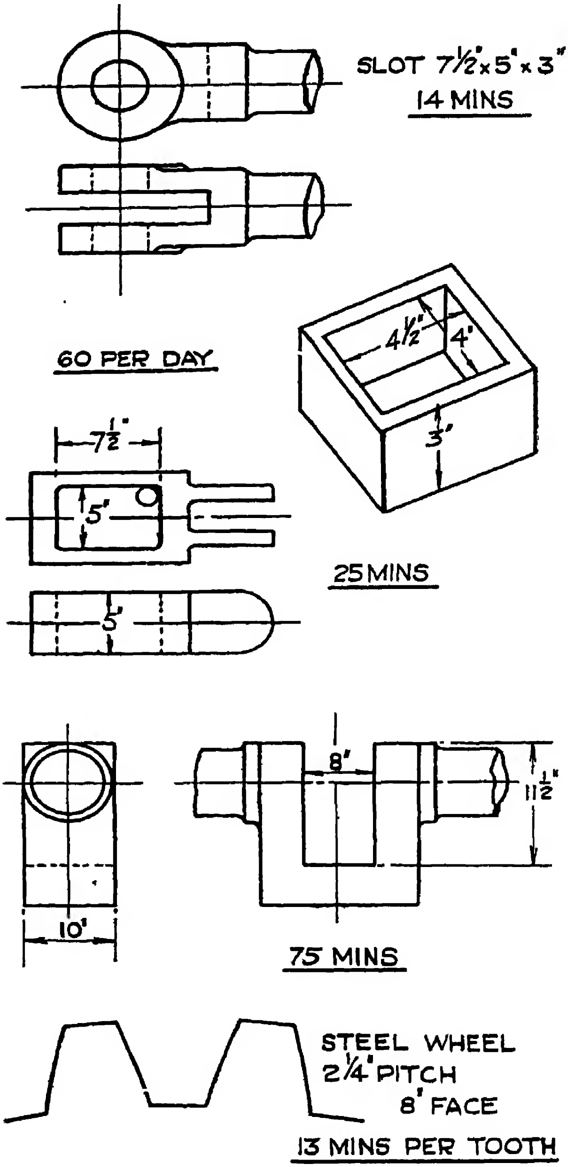


FIG. 2. SHOWING EXAMPLES OF WORK DONE ON THE PUNCHER SLOTTER AND THE TIMES TAKEN

the short end of the lever being connected by a forged rod to the slotting head.

In order to adjust for length of stroke, it will be seen that by loosening the three nuts referred to above and pulling on the flywheel the eccentrics slip round until

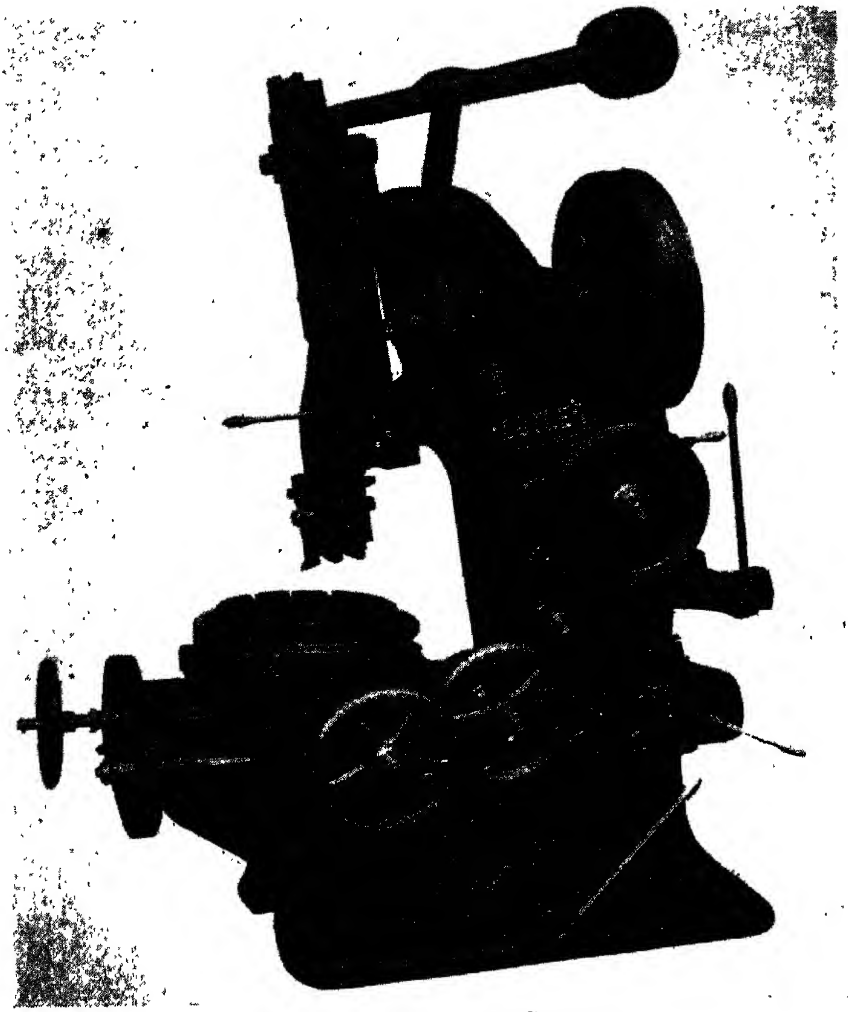


FIG. 3. THE TILTING SLOTTER

the dial gives the required stroke. Then, by retightening the bolts, the whole arrangement is locked together.

A number of examples of work done on the puncher slotter, with the times taken, is shown in Fig. 2. These include a crank web $11\frac{1}{2}$ by 8 in. completed in 75 min.

Tilting Slotters. The distinctive feature of the slotting machine shown in Fig. 3 is the tilting body. This machine is manufactured by The Butler Machine Tool Co., and has been designed specially for the purpose of machining external and internal tapers.

The body of the machine is in two parts, divided below the driving mechanism of the machine. The upper part revolves on a pivot by means of a worm and segment, with a locking device which ensures the two portions being firmly secured. The top portion of the machine will tilt 10 degrees backwards and forwards, and therefore tapers may be slotted on either side of the perpendicular.

The Whitworth quick-return motion is employed in driving the ram, and a range of four speeds provides approximately the same cutting speed on every 2 in. variation of stroke.

Feed Motion. The feed motion is operated by a large circular cam on the main driving shaft, and is fitted with a buffer spring device which renders its action almost noiseless, even when the machine is working at its fastest speed. A reversing and "stop feed" box is fitted on the working side of the machine so that the feed levers are always in tension in either direction, ensuring a uniform feed at the commencement of the cutting stroke.

The Ram. The ram is balanced by a direct counterweight adjusted to prevent shocks at the ends of the stroke. The "Tee" slots which carry the tool posts or holders are planed from a solid forging which is gibbed

and bolted to the main casting, thus avoiding the possibility of broken slots. The ram has "Vee" slides, and the faces are chilled and ground. Two loose strips are provided—one bolted direct on to the square flange of the main casting and the other provided with adjusting screws for taking up wear.

TOOL POSTS

A tool post used for general purposes on the puncher slotter is shown in Fig. 4. This type of tool post is constructed of cast steel, and is designed to carry two different size tools or tool bars. The tools may be carried either in front in a fixed position, or in any convenient position along the "Tee"-slotted side face.

Another type of tool post is illustrated in Fig. 5. This has a long support on the face of the ram, and permits the use of tools with a long reach over the table of the machine, and is particularly useful for slot cutting and end rounding. The post is made of forged steel, and arranged so that the operator may quickly revolve the cutter a half turn, bringing into operation either the square face or the half-round face of the cutter for cutting out round-headed slots.

TOOL HOLDERS

A simple form of tool holder used for holding small inserted cutters is shown in Fig. 6. This gives a relief to the tool on the non-cutting stroke, and prevents damage to the tool and work. Cutters of different shape, to suit the class of work to be machined, can be inserted and held in position by means of two set-screws.

SLOTTER TOOLS

Tools for use in the slotter may be forged from the solid bar or may consist of cutters inserted in some form of tool holder.

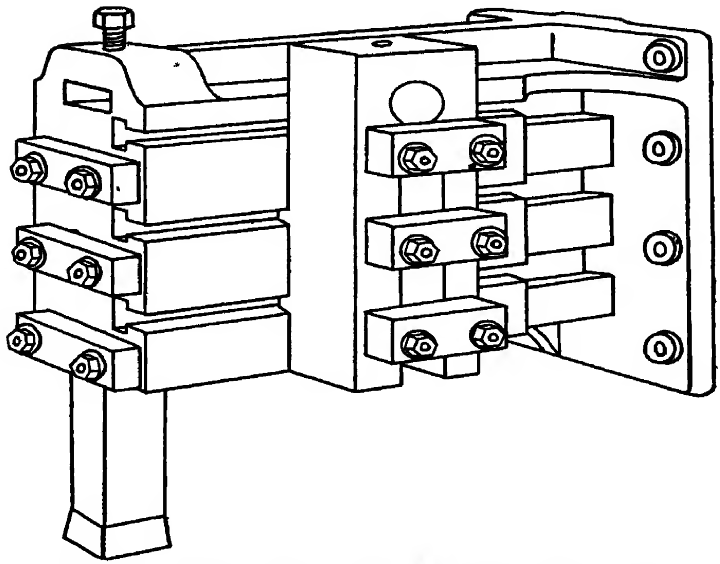


FIG. 4. TOOL POST FOR PUNCHER SLOTTER

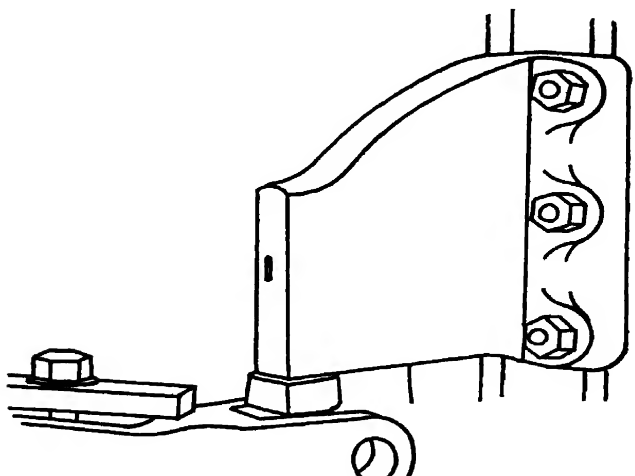


FIG. 5. TOOL POST SUITABLE FOR LONG REACH TOOLS

When a cut is being taken on the slotter there is less tendency to shift the work from the work table than is the case with the planer and shaper. The action of cutting presses the work on the table and tends to push the tool away from the job. For this reason it is

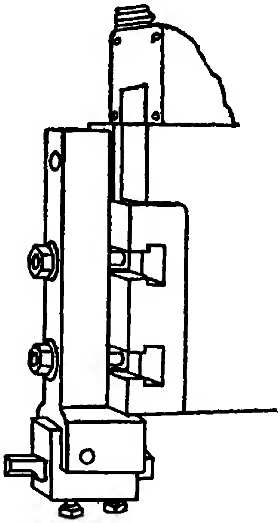


FIG. 6. RELIEF TOOL HOLDER FOR SMALL CUTTERS

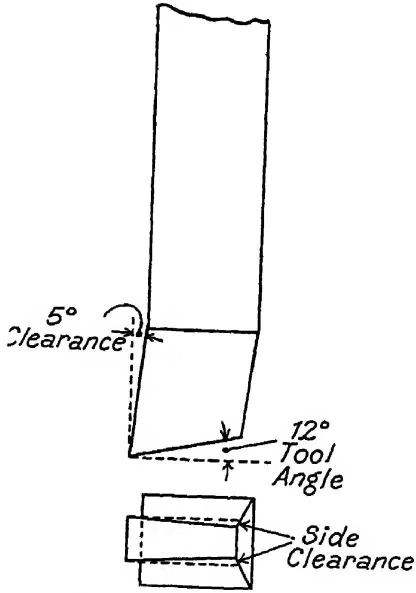


FIG. 7. SOLID TOOL FOR INTERNAL WORK

desirable to make the tools or tool holders of stiff section. In all cases the cutting edge of the tool should be as close as possible to the ram supporting dogs. Owing to the tendency of the tool to spring away from the work on the cutting stroke, it follows that a light and springy tool will tend to rub on the work on the non-cutting stroke unless some method of relief is given. This difficulty is overcome by using a spring relief block which allows the tool to spring away from the work on the up stroke, and this gives a longer life to the tool and prevents damage to the work.

The commonest form of solid tool is shown in Fig. 7. This type is mainly used on internal work where space is limited. The cutting edge is formed at the end of the tool, and may present a square or half-round

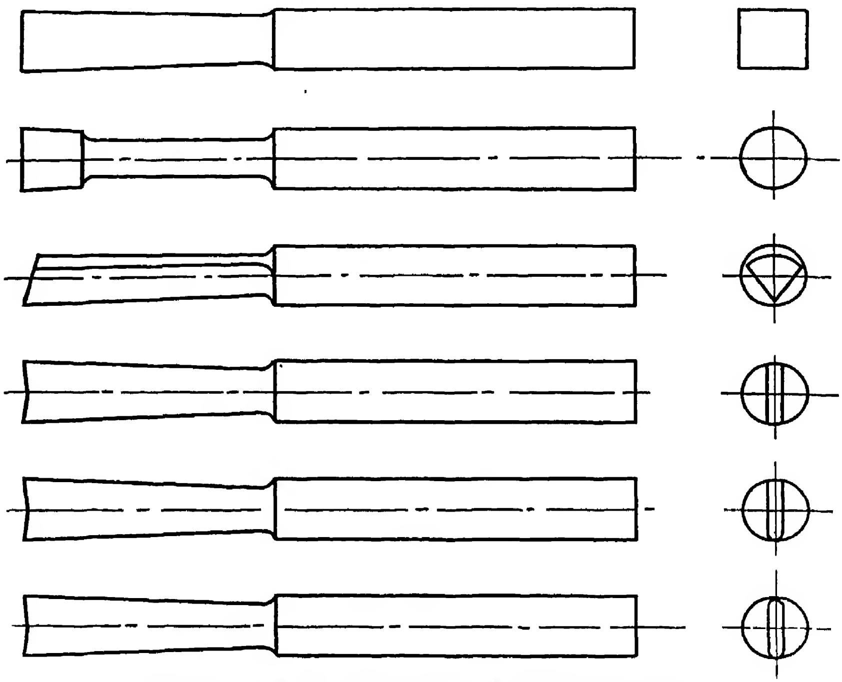


FIG. 8. SMALL SLOTTING MACHINE TOOLS

surface to the work. For external work, where plenty of space is available, a heavy cutter bar is best.

For some classes of work, such as slotting crank webs, it is often possible to use two tools, and for this purpose the cross-slide at the end of the ram is fitted with two slides, each carrying a pair of tool holders.

A set of six small slotting tools for precision work on a light tool-room machine is shown in Fig. 8.

The speeds and feeds used on the slotter are practically the same as those suitable for shaping.

SECTION XIX

MILLING

BY

G. T. CLARKE

SECTION XIX

MILLING

MILLING is a process of removing metal by means of rotary cutters. The cutters are made from tool steel, suitably hardened and finished on a cutter grinding machine. The cutters are of great variety, some being made to produce flat surfaces only, some to cut grooves such as keyways, etc.; others are ground to produce definite angles, like the slide rests on the lathe; cutters are also made to produce curved surfaces, such as gear teeth. All these types will be dealt with in due course.

HORIZONTAL OR VERTICAL MACHINES

However, the machine itself must be explained first. Milling machines are grouped into two classes, i.e. the horizontal and the vertical, which means that the shaft on which the cutters are placed is either parallel to, or perpendicular to, the table. All machines are of the "knee" type, unless built for a special purpose, which does not come within the range of the general engineer's shop. To-day one sees one-purpose machines in every case where great quantities of any particular machined parts are required. These machines are adaptations of the original milling machine and are no use for general work.

By "knee" is meant that the table projects from the main body of the machine, and on this knee rests the work which has to be milled. The knee is fitted with a moving table to hold the work. Figs. 1 and 2 show a Brown & Sharpe horizontal milling machine.

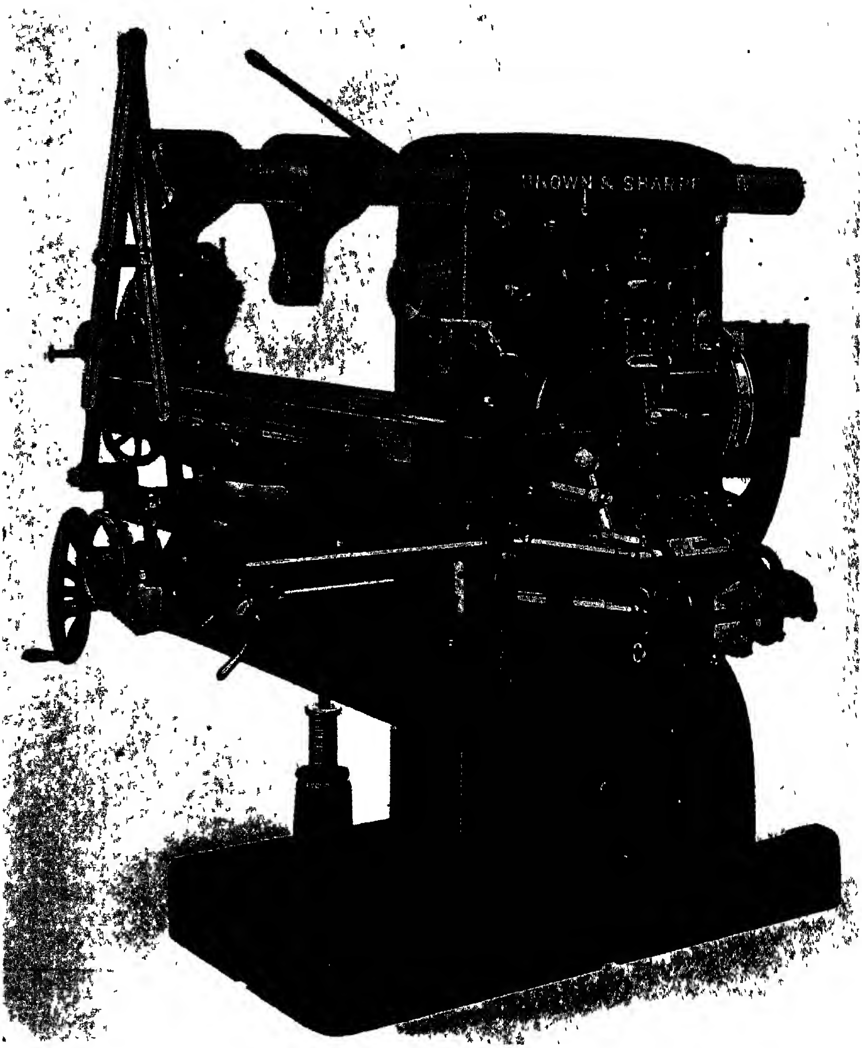


FIG. 1. BROWN & SHARPE UNIVERSAL CONSTANT DRIVE HORIZONTAL MILLING MACHINE

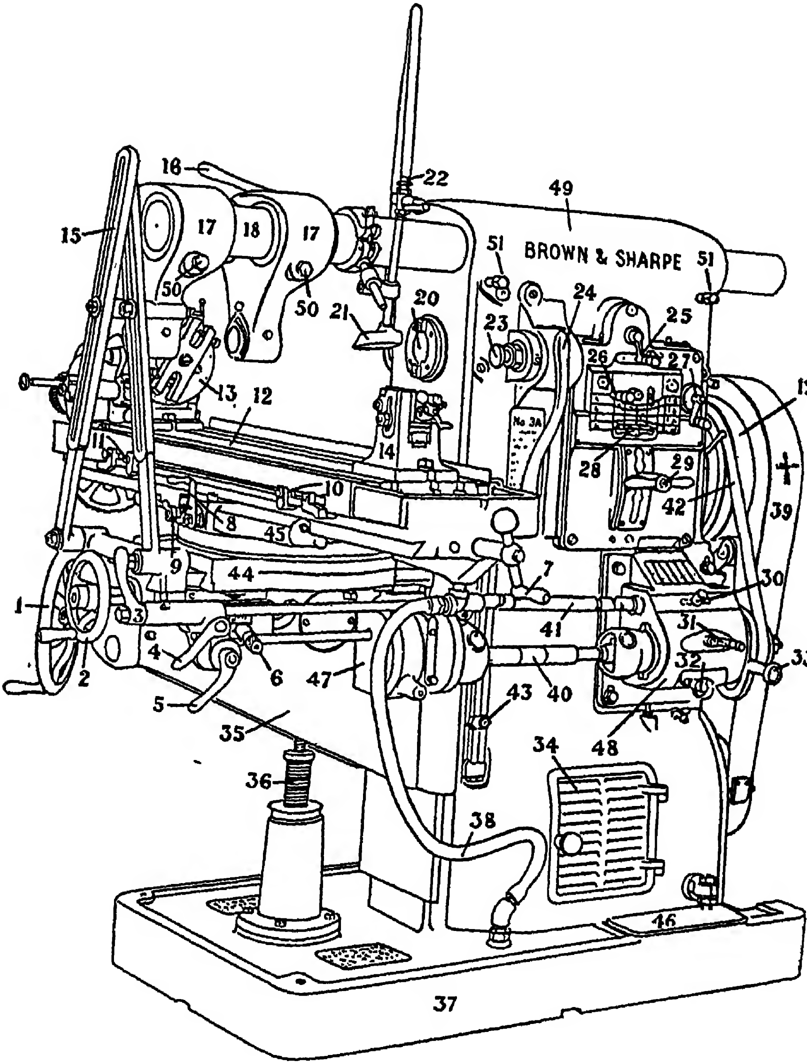


FIG. 2. OUTLINE DRAWING OF MILLING MACHINE SHOWN IN FIG. 1 WITH COMPONENT PARTS NUMBERED

(See Key on page 973)

ADJUSTABLE MOTIONS

The turner, with his lathe, machines the inside and outside of his job, either parallel or taper, and can surface it. This is carried out by means of a sliding saddle and the cross-slide rest, but with the knee of the milling machine the operator can not only move the table in and out from the main body of the machine, but can traverse it sideways and up and down. The table can also be swivelled to almost any angle within reason. From the foregoing it will readily be seen that a most complicated set of movements can be attained, even with the work simply bolted to the table. To add further to the difficulties of the beginner the work can be placed either between centres or chucked, and so revo ve whilst the table is performing a predetermined movement. The turning movement can be geared to the machine, so producing spirals of a definite "lead" as the movement is called. Again, the work can be set at any angle to the table and revolved, so that cams with varying radii can be produced. There appears to be no end to the complexity of movement in the modern milling machine.

Another feature is that the screws that give the table and the knee movement are accurately made and divided so that the operator knows the exact sum of the movement when he turns the handle that controls any particular part. By gearing in the indexing head rulings of great accuracy can be made, so besides being a metal remover it is a measuring machine as well.

The amount of metal removed is governed by the power of the machine, but, again, unlike the lathe where the tool has limited strength, the milling cutter simply pulls up if the feed is too coarse. This does not mean that cutters cannot be broken or that teeth cannot be burned by running too fast, but within ordinary range little damage can be done in that direction.

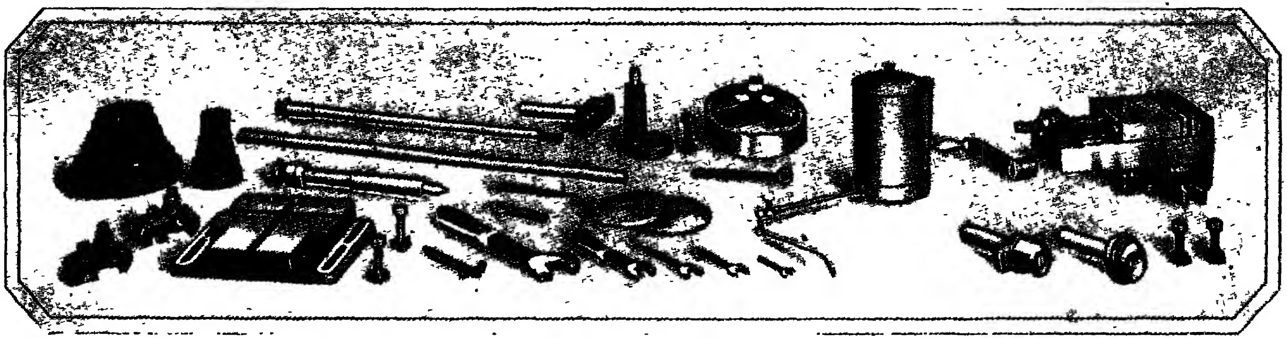


Fig. 3. Brown & Sharpe Universal Constant Drive Milling Machine Accessories

Key to Fig. 2 (page 971)

1. Handwheel for vertical feed
2. Handwheel for transverse feed
3. Power fast travel control lever for table
4. Power transverse feed control lever
5. Power vertical feed control lever
6. Locking device for transverse and vertical feed operating levers
7. Longitudinal table hand feed crank
8. Table feed trip lever
9. Table feed disengaging lever
10. Adjustable table dog
11. Adjustable table dog
12. Table
13. Spiral head
14. Footstock
15. Arm braces
16. Starting lever (left)
17. Arbor yoke
18. Overarm
19. Driving sprocket
20. Spindle
21. Cutter lubricant distributor
22. Flexible tube for cutter lubricant
23. Knob for fine adjustment of spindle
24. Starting lever (right)
25. Spindle speed change lever
26. Spindle reverse lever
27. Back gear operating lever
28. Knob for sliding tumbler gear
29. Tumbler gear locking lever
30. Feed index knob
31. Feed change lever
32. Feed change lever
33. Tumbler gear lever
34. Door to motor compartment
35. Knee
36. Knee elevating screw
37. Coolant tank in base
38. Flexible tube for return of cutter lubricant
39. Chain guard
40. Telescopic table feed shaft
41. Power fast travel control shaft
42. Power fast travel drive belt
43. Vertical feed trip dog
44. Clamp bed
45. Swivel
46. Cutter lubricant reservoir cover
47. Feed reverse gear case
48. Variable feed case
49. Column
50. Clamp bolt for arbor yoke
51. Overarm clamp bolt

The milling machine is made to run in either direction, because some work requires a change of cutting direction without unshipping from the table; also the operator may need the cutter to cut in one direction whilst the table moves in the other or vice versa.

COOLING THE CUTTER

The cutter is cooled by some form of cutting lubricant pumped from a tank under the machine. This pump operates in either direction, so that the reversal of the machine matters not at all. The table is provided with a flexible waste pipe to the tank, taking away the cutting oil which has been pumped through a similar flexible tube, which is fixed so that the jet of oil generally plays on the cutter at the point where it is actually cutting. This not only cools the cutter at the place of heat generation, but washes away the hot chips. The oil is strained before going through the pump.

ADVANTAGES OF THE HORIZONTAL MACHINE

The average general engineer's shop prefers the horizontal machine to the vertical, because a great variety of work can be done on the former that cannot be machined on the latter; also the horizontal machine, with the aid of attachments, can be converted into a vertical spindle miller with ease, and these attachments not only permit the same class of cutter to be used, but the attachment itself can be used at almost any angle, as when cutting cams, etc.

From the foregoing it will be seen that the operator of a milling machine must be above the average mechanic. He need not be so skilled with his hands as the fitter, but all his calculations must be deadly accurate, as the machine permits no errors. He must keep his machine spotlessly clean, as chips cause loss of accuracy in all working parts. In setting up his

work he must have everything ready when he starts the machine. If he is not sure of his figuring he should go over it again, as the first wrong cut will put the job on the scrap heap. The full depth of cut need not always be arrived at the first time, and it may not be even needed, but it matters little if it is the first or second cut if the keyway is out of centre, the job at an incorrect angle, or the wrong gear wheel interposed or a spiral. The same accuracy applies to the indexing head used in wheel cutting. The right plate may have been affixed, but if the graduated sector is one hole out the job will be scrapped on the second tooth being cut.

CUTTER ARBORS

The cutters are placed on the shaft, or arbor as it is technically called. The driven end of the arbor is fitted into a taper hole in the driving spindle and kept from slipping by a dog near the end. This end is secured in the spindle by a long bolt that goes right through the spindle itself and screws into the arbor with a left-handed thread. To remove the arbor, first unscrew and take out the long bolt from the driving spindle, insert a brass or copper rod some 10 in. longer than the bolt and larger in diameter, using it as a ram to tap out the arbor. It is useless to give the arbor heavy blows, as it will only be tightened thereby. If it should get very tight, patience and light blows will succeed where impatience and the hammer will fail.

With the average machine three arbors will be in use of $\frac{7}{8}$ in., 1 in., and $1\frac{1}{4}$ in. diameters. The cutters are held in place by a series of collars secured by a large left-handed nut. Every time the arbor is dismantled the collars and arbors should be washed in paraffin to remove the chips or swarf.

If on re-assembling any chips get between the faces

of the collars the arbor will be distorted and its accuracy lost. One of the collars will be found hardened and ground to run in the overhanging arm, or arbor yoke. This yoke is telescopic and removable when changing arbors or cutters. For light work the yoke need not be supported, but with heavy cuts the arm braces should be used.

In securing the cutters, fit them on the place desired with the necessary number of collars and the hardened

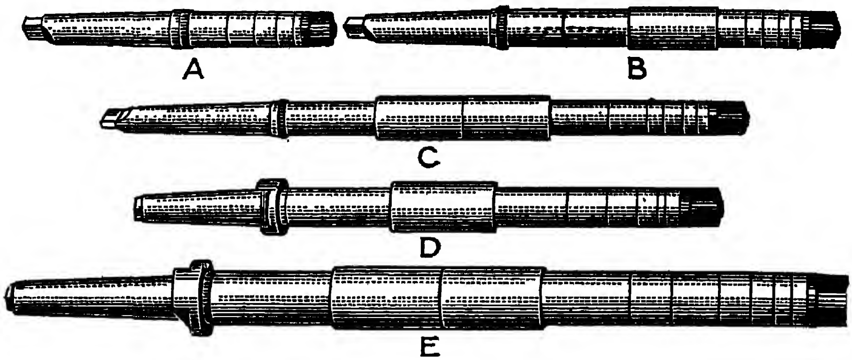


FIG. 4. CUTTER ARBORS FOR USE IN BROWN & SHARPE MILLING MACHINE, WITH THREADED-NOSE SPINDLES

one in the correct position for the arbor yoke, bring the yoke into position and lock it there, then with a spanner fasten the nut that secures both collars and cutters. It is obvious that if the nut is tightened without the arbor being adequately supported it will be bent. It is not always necessary to remove the arbor to change cutters unless one with a different diameter hole is to be used.

Again, it is mentioned that strict attention to detail and calculations, plus cleanliness, makes the good operator. It is impossible for him to change his mind once the machine is started. Fig. 4 illustrates some typical cutter arbors.

SPEEDS

Milling machines in many instances are driven by cone pulleys and usual back gear, as on the lathe. The feed of the table is, in a number of cases, also cone driven, but however the feed is obtained on the cone pulley machine it is dependent on the spindle speed of the machine itself. If the operator desires the spindle to rotate at the lowest speed (with the back gear in) the feed will also be lowered in proportion even if the highest feed is engaged. This applies to both cone and gear-box feeds.

Since 1904 machines have been built on the constant-speed pulley principle. The machines have one large pulley, and the spindle is driven from this pulley through a gear-box. The feeds are also driven from this constant-speed pulley through a gear-box, and are quite independent of one another. Assume the operator has set his machine to cut a groove in a shaft, using a $2\frac{1}{2}$ in. diameter cutter. He finds the cutter to be blunt, and changes it to one 5 in. diameter, not having another, the same as the original. This cutter, being twice the diameter of the original, will have twice the surface speed at the same spindle speed, therefore the spindle speed must be halved. On the constant speed machine, moving a lever on the spindle gear-box effects the change whilst the speed remains unchanged. On the cone pulley machine the feed also would have to be reset. The extreme ranges on constant speed machines are greater, and there being only one pulley it is wider, thereby transmitting more power for a less space occupied.

AUTOMATIC FEEDS

The machine should be fitted with automatic feeds in all three directions, the gear-driven feed generally producing cleaner and more constant surfaces. With

small jobs the hand feed is often used because the cut is over before the automatic feed can be engaged. From the illustration the various table controls on a Brown & Sharpe medium-sized machine can be readily seen, also the longitudinal drive of the table is generally fitted with a fast travel wheel to facilitate returning the table to its original position after a cut. This saves much handle turning, as when cutting long splines on a shaft.

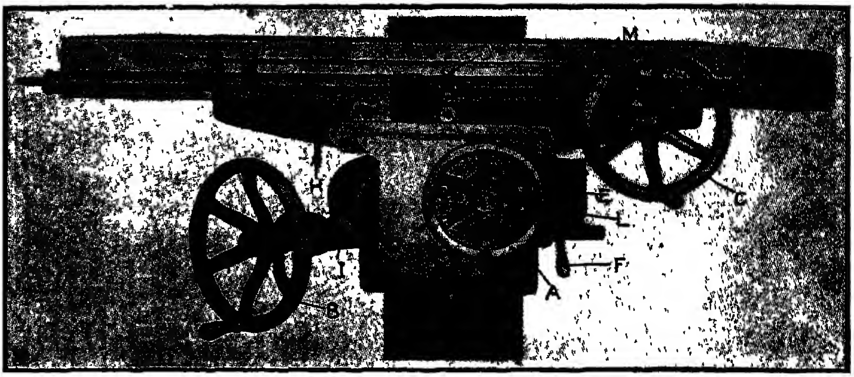


FIG. 5. AUTOMATIC STOPS ON TABLE

A = Transverse hand feed
B = Vertical hand feed
C = Longitudinal hand fine adjustment
D = Longitudinal automatic feed trip and reverse lever
E = Transverse automatic feed trip lever
F = Vertical automatic feed trip lever
G = Lever for disengaging table feed
H = Transverse saddle clamp
I = Vertical knee clamp
J = Feed reverse operating lever
K = Adjustable dials graduated to thousandths of an inch
L = Knob for locking transverse and vertical feed operating levers
M = Power fast travel control lever
N = Centralized oiling for table and saddle bearings
O = Table clamp
P = Adjustable table dog

USE OF STOPS

Stops are also fitted to machines so that the cut can be set to any predetermined length and depth. With the longitudinal traverse the lever *D* (Fig. 5) is set over opposite to the required direction of table travel, the trip-stop *P* returning the lever to the vertical when it reaches it and automatically stopping the table. This trip-stop can be placed anywhere along the table

desired by the operator. When using end mills, as in cutting sunken keyways, it is advisable to use a definite stop both ends of the table, the automatic device not being accurate enough for such work. Assume a $\frac{1}{2}$ in. wide sunken keyway has to be cut 2 in. long. The stops will be set to $1\frac{1}{2}$ in. and traverse carried out by hand, because any attempt to overstep the mark, specially when nearly at the required depth, will be fatal to the cutter. In other instances, the definite stop can be set so that when commencing a cut the cutter cannot be run back against the driving dog or chuck, as when fluting reamers. The automatic stop is then used for stopping the table at the end of the cut.

RATE OF FEED

The actual feeds are left to the operator, who will soon learn the feed that suits any particular job. Ordinarily, the order of speeds is as on the lathe with the same class of metals. The apprentice will generally have worked a lathe prior to a "miller," therefore speeds should not present any actual difficulties. Milling machines run in either direction, according to the type of job, and the direction of feed is an important factor. It is obvious that an operator when cutting cast iron would not wish the cutter to be continually cutting into the scale of the casting. He would arrange the rotation so that the cutter broke through the scale from the underside, with the consequence that the cutter always met the soft metal first. It is also obvious that the direction of feed should be opposite to the rotation of the cutter to prevent drawing the work in and taking too deep a cut. This applies more especia ly when the machine shows signs of wear in the table screws. There are instances when the table has to work in the same direction as with thin cutting saws and very deep slots, when there is a tendency for the cutter to run out of line unless

both feed and rotation are in the same direction. When cutting in this manner see that the gib screws are temporarily tightened to take up lost motion and, if necessary, a counterweight can be attached with a chain over a pulley to hold back the table from the greediness of the cutter. Fig. 6 shows correct and incorrect cutting at *A* and *B* respectively.

For very accurate limits it is impossible to finish the

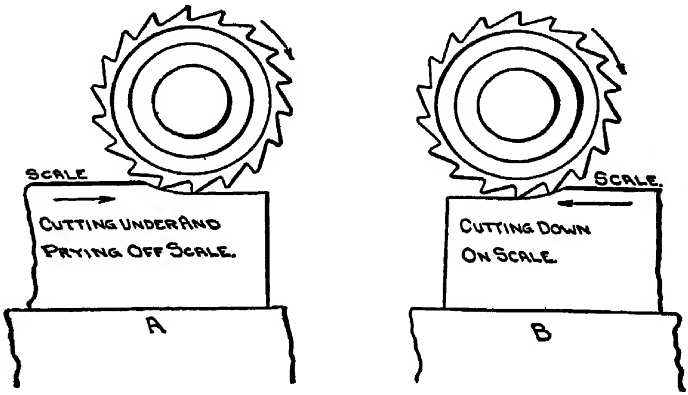


FIG. 6. CORRECT AND INCORRECT CUTTING

job in one cut. A second and lighter cut at a faster speed or smaller feed will produce closer limits and finer finish. In cutting down two sides at once the cutters can be set apart on the arbor by the collars and spacing washers, trial cuts being taken until finality results. These trial cuts are only worth while when quantities of the same article are to be produced. As an instance, it would not be worth while spacing two cutters specially to cut squares or hexagons on three or four special bolts. Even on small well-finished hexagon bolts it is as well to take the second cut if cutter marks are to be eradicated.

There is always a certain amount of lost motion on the feed screws, even on a new machine, and as it

ages this lost motion increases; therefore always eliminate this backlash before commencing the actual measurements of the feed. This is done by giving the handle a turn the opposite way to the direction desired, then reversing the action and taking note when the cutter comes in contact with the work. If the handle has to be reversed during any operation, always note the graduation mark before turning the handle, so that it can be easily reset with any addition necessary.

MACHINE FOUNDATIONS

The milling machine should be set down on concrete, as floor vibrations are imparted into the work and accuracy of the machine impaired. If on a wood floor the machine should certainly be set over a beam or support, and not in the centre of a span. The machine should also be set dead level, and as it is grouted in, a spirit level laid on the table should be consulted from time to time. The level should be laid both longitudinally and transversely, so as to assure its being dead level both ways. If the machine is truly laid the spirit level can be used in setting up work, and so save time and labour with the sur ace gauge, also the awkward shape of castings may make it difficult to use the gauge.

HOLDING DOWN THE WORK

Small work when held on the table should be released somewhat after the coarse cuts have been taken, so that when the finishing cut comes along the job has taken up its own position when relieved of bolting-down stresses. This is most important, as it is so easy to clamp work down and set up ulterior strains, so that when the job is taken off the machine its surface is found to have a twist or hollow.

The illustrations give some idea of clamps, bolts, steps, and jacks used. Many of them will be in ranges

of sizes, also the operator will, from time to time, make clamps of special design, all of which should be preserved.

The clamping bolt should be placed as near the job

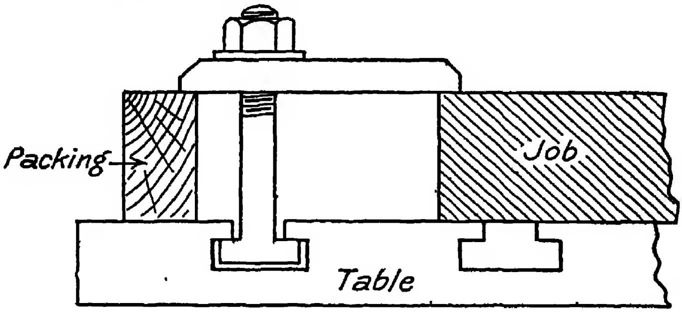


FIG. 7. INCORRECT METHOD OF HOLDING DOWN WORK—JOB IS TOO FAR FROM CLAMP BOLT

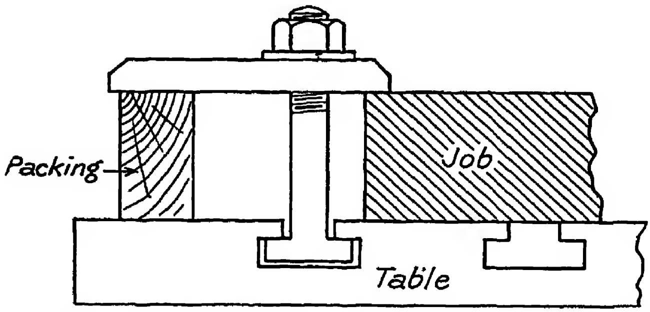


FIG. 8. CORRECT METHOD OF HOLDING DOWN WORK

as practicable, so that the main pressure is on the job and not on the packing piece. This also helps to lessen table strains. The job need not be held down very tightly if a stopping block is bolted to the table to keep the job from being forced along it by the pressure of the cutter's action. When fastening down the job, especially if its length is nearly the range of the machine's traverse, see that the cutter will go from end to end before final arrangements are made (see Figs. 7 and 8).

The cutter should always be placed on the arbor as near the spindle nose as possible. This not only takes the strain off the overhanging yoke bearing, but assures the weight of the job being near the main body

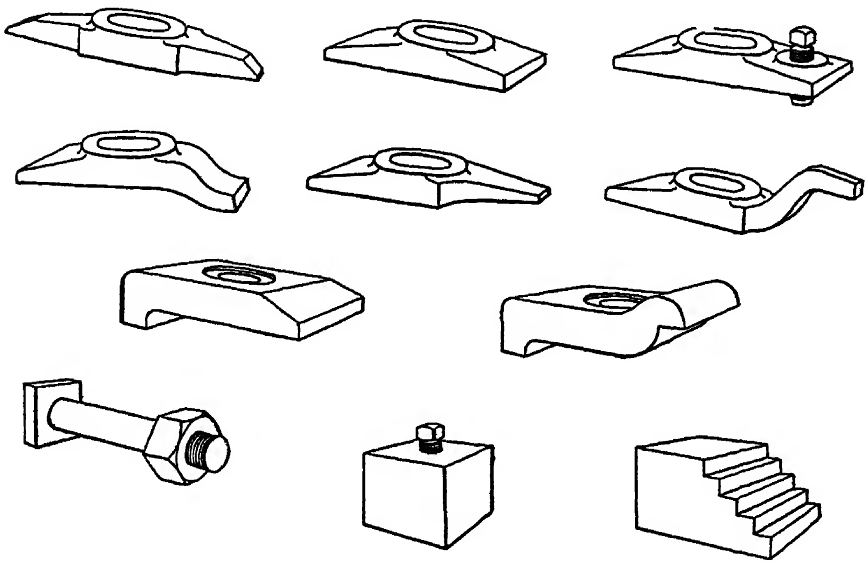


FIG. 9. VARIOUS HOLDING-DOWN CLAMPS, BOLTS, JACKS, ETC.

of the machine, and taking the strain from the knee as well.

Many jobs are held in the vice, the jaws of which are ground hardened steel, unlike the fitter's bench vice. All milling machine vices are made with greater accuracy, and should be retained for that machine only and not loaned to the drilling machine, where it will get rough usage and soon lose the excellent parallel finish of its jaws. The average vice is made to swivel, and has graduations marked around the base to show the angle to which it is swivelled. On the underside are two dogs, which should be a fairly tight

FIG. 10A. TABLE VICE

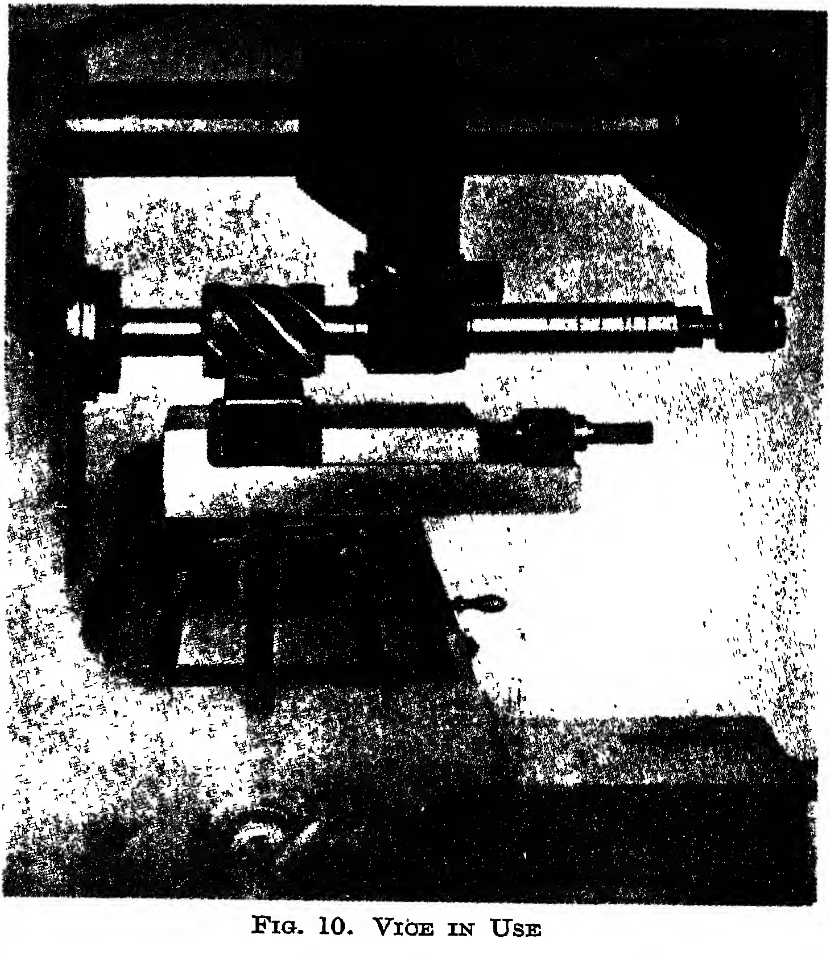


FIG. 10. VICE IN USE

fit in the table slots, assuring the zero mark being in the correct position. To check the accuracy of the zero mark, lay in the vice a long straight-edge and, with the aid of a square on the table, swivel the vice until the straight-edge is parallel with the table slots. Again, it can be checked by lightly clamping a square in the vice, having the square on its side. Remove any cutter from the arbor and have only plain collars thereon. Raise the knee until the square is level with the arbor, and then move the table along until the square comes in contact with the arbor. They should be exactly parallel to one another. The illustration shows a vice in use.

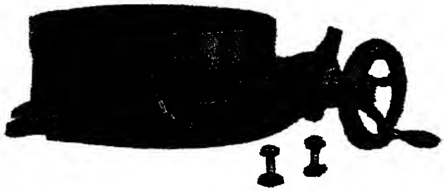


FIG. 11. CIRCULAR MILLING ATTACHMENT

A circular milling attachment is also illustrated. It is not for attachment to the gearing of the machine, but is turned by hand. The table can be wholly revolved and is graduated to read to divisions of 5 min. each; also on the front is a chart giving the settings to produce work with 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 16, 18, 20, and 24 sides.

FIG. 12. TILTING TABLE

TILTING TABLE

Where much taper work has to be carried out a tilting table is a valuable asset. The indexing head, with its centre, can be fitted to this table for continually fluting reamers and other taper jobs. The table,

when set, can be removed from the machine and set aside until again required, without disturbing the taper to which it has been set.

THE SPIRAL AND INDEXING HEAD

The indexing head is part and parcel of the universal milling machine, and even of the plain milling machine, because in the general engineer's shop the majority of

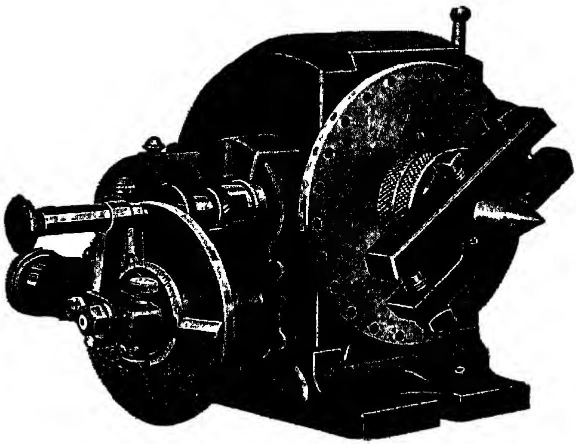


Fig. 13. Brown & Sharpe Indexing Head

milling jobs consist of producing hexagon- and square-headed bolts, cutting keyways, splines or squares on shafts, fluting taps and reamers, and many other jobs all requiring the circle to be accurately divided. The indexing head is used to divide the circle into any number of required parts. On the head can be fixed a chuck to hold work, as on the lathe, or the work can be placed between centres. Fig. 13 shows the head with centre and driving dog.

There are two types of indexing heads, the plain and the differential; both are of the same principle, the latter being more complicated and made to deal with

spiral work as well as enabling the operator to obtain a greater number of divisions.

THE PLAIN HEAD

To deal with the plain head first. The head itself consists of a substantial casting within which is mounted a revolving hollow spindle. This spindle is turned by hand. The spindle is fitted with a worm wheel having 40 teeth, and driven by a worm shaft screwed with a single thread. The end of the shaft is fitted with a crank and handle. Consequently one must turn the crank forty times to revolve the spindle once.

Before going further into the system of dividing the circle it will be readily seen that if, after running the cutter along a shaft (so producing a flat), the crank handle is turned *exactly* ten times and the cutter run along again, we will produce another flat at right angles to the first. If the crank is turned another ten times and a cut taken, then another ten and the last cut taken, the shaft will either become a square, or at least will have four flats thereon at 90 degrees each. The fact is we have divided the circle into four equal parts. Should the crank handle only be moved five revolutions, the circle will be divided into eight equal parts. All this is very simple, but when it is desired to produce a hexagon it means we have also to divide the crank revolutions into parts as well. Our formula is $40 \div 6 = 6\frac{2}{3}$, therefore to form a hexagon the crank must be turned six complete revolutions and two-thirds of a revolution. To carry this out easily the various manufacturers have provided the head with a number of circular plates that in themselves have been carefully spaced so that the crank handle can be held, or stopped, in any desired place. Holes are drilled in the plates so that a spring pin on the handle can be arrested at the desired division. The plates are called division plates,

and using the Brown and Sharpe head as example, we have three plates having circles on them with the following numbers of holes.

Plate 1:	15, 16, 17, 18, 19, 20	holes.
,, 2:	21, 23, 27, 29, 31, 33	,,
,, 3:	37, 39, 41, 43, 47, 49	,,

The circles of holes all commence on a single line radiating from the centre, and are numbered on that line, making it easy when selecting any circle. The spring pin when fitted into any hole stops the spindle from moving whilst a cut is on, besides which the head is provided with a clamp to assist the spring pin in retaining its position. To fix a plate, the handle is removed and the desired plate is attached by 2 countersunk screws (not seen in any of the sketches). The handle is then replaced with the spring pin in the zero hole of the circle required.

To revert to the hexagon, we have arrived at six complete turns and two-thirds of a turn, but there is no plate with only 3 holes, therefore the value must be raised $\frac{2}{3} \times \frac{11}{11} = \frac{22}{33}$; therefore, if the 33 circle is chosen on Plate 2 and the first cut taken with the pin in the first (zero) hole, it will only be necessary to turn the crank six times and 22 holes to produce the second side. After taking the cut we make another six turns and 22 holes *from the place where the pin was last*, and find that we have stopped 11 holes past the zero from whence we started. Another cut and the same procedure as to turning the crank brings the pin back to the zero hole, and proves the movements to be correct, i.e. $6\frac{2}{3} \times 3 = 20$, or one-half the revolution of the spindle. Proceed to cut the remaining sides. It will be seen in cutting the hexagon that the 39 circle on Plate 3, or the 18 circle on Plate 1 could have been used by spacing either 26 or 12 holes respectively.

With the Cincinnati milling machine only two plates are used containing the following holes—

Plate 1: 24, 25, 28; 30, 34, 37, 38, 39, 41, 42 and 43 holes.
,, 2: 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66.

The ratio of the spindle and worm shaft is the same, i.e. 40. These being the two chief principles of indexing, the holes are only duplicated in four instances—39, 41, 47, and 49. Notwithstanding all these circles of holes, it is impossible to obtain certain divisions. It will be found with the Brown & Sharpe system that it breaks down at 51, and with the Cincinnati at 61 and many higher numbers, such as 63, 67, 69, 71, 73, 77, and so on.

THE DIFFERENTIAL HEAD

As one often wishes to cut teeth of these numbers in wheels it is certain that some method has been devised to overcome the difficulty, because many wheels are seen to have such teeth, and this is where the differential indexing head is used. We have mentioned the division plates fixed to the side of the plain indexing head. *Suppose the plate to be fixed to the spindle and move with it?* When the crank handle is turned once the plate will turn one-fortieth of a revolution. By so doing in one complete revolution of the spindle, the spindle itself will only divide the circle into thirty-nine parts instead of forty because, the plate moving with the crank, it will have *lost* one-fortieth at each turn. Suppose the plate and crank handle are arranged to go in opposite directions, then instead of following the crank it will be moving against it, and the circle will be divided into forty-one parts instead of forty, because the spindle will *gain* one-fortieth per revolution of the crank handle. The spring pin will, of course, be placed in exactly the same (zero) hole every time. This hole gradually performs a circuit of its own, either with

or against the spindle as required, and it is on this basis that differential indexing is carried out. The change wheels supplied with the Brown and Sharpe head enable the operator to divide the circle from 2 to 382 divisions and many others exceeding this number. The wheels are used precisely as the change wheels on the lathe, and the head is so arranged that a wheel can be placed on the spindle and on the division plate with intervening movable studs to carry the idling wheels which, when interposed, change direction and help to engage the spindle and plate wheels. As with the lathe, the gearing is sometimes compounded.

The sectional illustration (Fig. 14) shows the construction of the plain head. The hollow spindle is rotated by means of the worm wheel *B*, which is driven by the worm shaft *A*. *C* is a large division plate on the front part of the head to index rapidly divisions of 3, 4, 6, 8, 12, and 24 divisions without using the other plates. This large plate is locked in position by the sliding pin *D*. The worm shaft *A* can be disengaged (there is a reason for this, as will be seen with spiral milling) by rotating the knob *E* a quarter turn with a pin spanner. When turned in a direction opposite to the arrow marked on the knob it loosens the nut *G* that clamps the eccentric bushing *H*. By turning together *E* and *F* the bushing *H* will revolve, throwing the worm shaft out of gear with the worm. The operation is reversed to engage worm and shaft.

The wheels used in differential indexing have the following numbers of teeth—24 (2 gears), 28, 32, 40, 44, 48, 56, 72, 86, and 100.

Before proceeding with differential indexing it is as well to explain the methods of using the crank handle, locating holes, regaining position (if once lost), use of the sector to save counting odd holes, etc. Immediately behind the crank handle and in contact with the

division plate are two arms which can be closed together or spread apart by releasing the screw *A* shown in Fig. 15, page 992, the graduated sector and division plate. To use the sector loosen the screw, and when the pin is in the zero hole (prior to commencing operations) set the left-hand arm against the pin, then set the right-hand arm the other side of the next hole, and covering

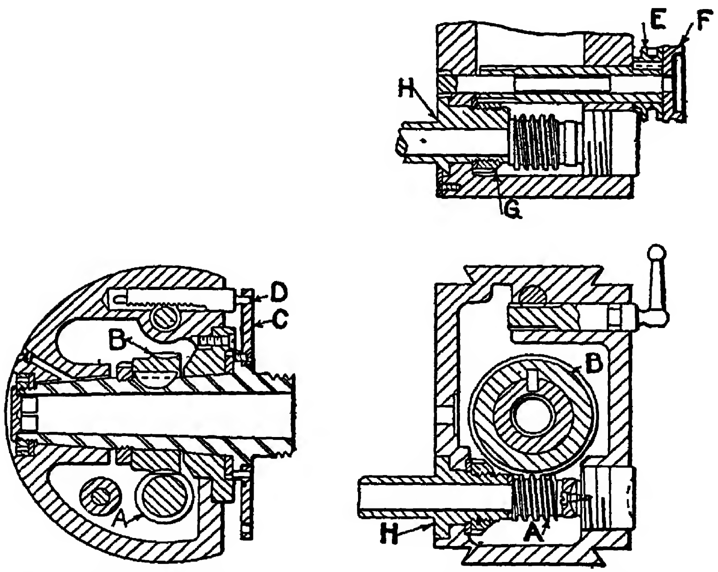


FIG. 14. SECTIONAL DETAILS OF PLAIN INDEXING HEAD

the following hole, that the pin will have to go into, lock the screw. When the cut is finished it will only be necessary to turn the crank handle the requisite number of complete revolutions and then on a little further until the pin nearly reaches the right-hand arm, when it will fall into the hole required. Whilst the cut is in hand the tightened arms can be slipped around until the left-hand arm again touches the pin, when it is automatically set for the next turning of the crank. With the Brown & Sharpe head a table is issued to

save all calculations, and as the sector is graduated it is only necessary to refer to the figures at the right-hand side of the column to know where to set the arms. The graduations do not record degrees, and are only a means of quickly attaining the spacing desired.

The crank handle is adjustable so that delicate location can be made. This enables the crank to be brought to the nearest hole without disturbing the work, especially if it has once been commenced. To adjust the crank operate the knurled screws *A A*, unscrewing one and screwing up the other, thus slightly rotating crank until the pin drops in the hole. To adjust the work to the plate, the pin is dropped into the hole first when, by turning the knurled screws, the work rotates until in the desired position. The crank is also adjustable to the circle diameters.

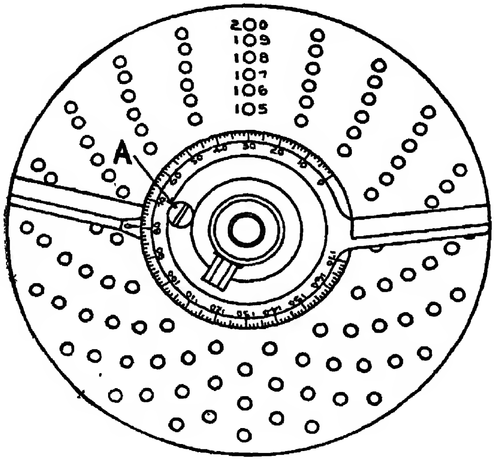


Fig. 15. Sector for Subdividing Circles

As explained, differential indexing is carried out by turning the crank through a certain number of holes, the crank turning the spindle, and the spindle turning the plate. Our simple explanation was with the actual "lead" of the head itself, namely, a ratio of 1 to 40. By inserting various gears and changing their directions, we can obtain other ratios and multiples of ratios. Although tables are printed to assist the operator, it is as well for him to know how to do it himself. He is then

a sure workman, and can check any given calculation. Any operator who does not know why such a thing happens cannot call himself a first-class mechanic. It is part and parcel of his business to know what he is about, because the day must come when he will have to figure out some problem on his machine that is not contained in any table. The turner is supposed to be able to calculate his wheels when screw-cutting — why not the milling machine operator?

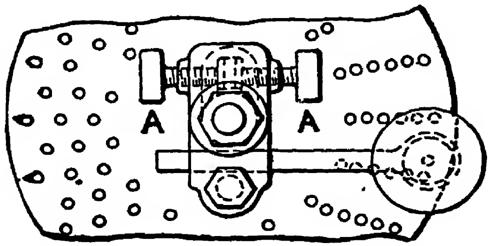


FIG. 16. SHOWING METHOD OF ADJUSTING CRANK HANDLE

With differential indexing it is not imperative to select any particular division plate, but it is best to choose one with a number producing factors that are contained in the change gears supplied, for if the number of holes in the division plate H (Fig. 14) contains a factor not found in the gears, it will be difficult, and perhaps impossible, to obtain the correct ratio in the wheels used between the spindle and the division plate x, unless the factor is cancelled by the difference between the number of holes in the division plate and the ratio of the head HV, and the number of divisions required and the number of holes taken at each indexing Nn, or unless the number of divisions N contains the factor.

When the number of holes in the division plate and the ratio of the head HV is *greater* than the number of divisions required and the number of holes at each indexing Nn, and the gearing is simple, use one idler only. If compound, use no idlers.

When the number of holes in the division plate and

the ratio of the head HV is *less* than the number of divisions required and the number of holes at each indexing Nn, and the gearing is simple, use two idlers. If compound, use one idler.

Observe the above rules carefully, also note that the same two rules govern the actual calculations of the gearing proper.

Select the number of holes taken at each indexing n, so that the ratio of gearing will not exceed 6 to 1 on account of stress on the gear teeth.

The formula for gearing is—

N = number of divisions required.
H = number of holes in division plate.
n = number of holes taken at each indexing.
V = ratio of head = 40 on Brown & Sharpe head.
x = ratio of train of gearing between spindle and plate.

$$\left.\begin{array}{l} S = \text{gear on spindle} \\ G_1 = \text{first gear on stud} \end{array}\right\} \text{Drivers.}$$

$$\left.\begin{array}{l} G_2 = \text{second gear on stud} \\ W = \text{gear on plate} \end{array}\right\} \text{Driven.}$$

$$x = \frac{HV - Nn}{H} \text{ if } HV \text{ is greater than } Nn.$$

$$x = \frac{Nn - HV}{H} \text{ if } HV \text{ is less than } Nn.$$

$$x = \frac{S}{W} \text{ for simple gearing.}$$

$$x = \frac{SG_1}{G_2W} \text{ for compound gearing.}$$

Example—

Number of divisions required = 59 (N).

Before proceeding further the operator decides the division plate he will use and the number of holes he will index. From these he will be able to define (x).

Assume the 33 circle is chosen (H) and the number of holes decided to index at a time to be 22 (n). Ratio of head = 40 (V), then

$$x = \frac{(H \times V) - (N \times n)}{H} = \frac{(33 \times 40) - (59 \times 22)}{33}$$

$$= \frac{22}{33} = \frac{2}{3} \text{ or } \frac{S}{W}$$

The operator selects gears 32 and 48 because

$$\frac{S}{W} = \frac{2}{3} \text{ or } \frac{2 \times 16}{3 \times 16} = \frac{32 \text{ gear on spindle.}}{48 \text{ gear on division plate.}}$$

As HV ($33 \times 40 = 1320$) is greater than Nn ($59 \times 22 = 1298$) and the gearing is simple, only one idler is required.

EXAMPLE—

Divisions required	= 319 (N).
Division plate selected	= 29 (H).
Holes to be indexed (selected)	= (4 (n).
Ratio of gears required	= (x).
Ratio of head	= 40 (V).

$$x = \frac{(N \times n) - (H \times V)}{H} = \frac{(319 \times 4) - (29 \times 40)}{29}$$

$$= \frac{1276 - 1160}{29} = \frac{116}{29} = \frac{4}{1} = \frac{S}{W} \text{ or } \frac{12}{3} = \frac{3 \times 4}{1 \times 3}$$

$$= \frac{SG_1}{G_2W} = \frac{(3 \times 24) \times (4 \times 16)}{(1 \times 24) \times (3 \times 16)} = \frac{72 \times 64}{24 \times 48}$$

Wheel 72 goes on the spindle.

,, 64 ,, ,, stud (1st).
,, 24 ,, ,, ,, (2nd).
, 48 ,, ,, division plate.

It was here necessary to compound as no wheels can be found to give a 4 to 1 ratio.

HV being less than *Nn*, and the gear being compound, one idler is required.

Before leaving the formula, which may seem so bewildering to the young mechanic, perhaps it would be as well to put into figures our first explanation of the differential method, and show how 39 and 41 divisions would appear if worked out. Of course, one does not use any gears at all in actual practice because there is no necessity, but the fact that the full number of holes in the division plate can be used simplifies matters in bringing home to the operator the actual working of the system. EXAMPLE—

Divisions required	= 39 (N).
Division plate selected	= 20 (H).
Holes to be indexed	= 20 (n).
Ratio of head	= 40 (V).

In this instance *HV* is *greater* than *Nn*, therefore the formula is—

$$\frac{\left(\overset{\text{Plate } H}{20} \times \overset{\text{Head ratio } V}{40}\right) - \left(\overset{\text{Divisions } N}{39} \times \overset{\text{Holes } n}{20}\right)}{20 \text{ Plate } H} =$$

$$= \frac{800 - 780}{20} = \frac{20}{20} = \frac{1}{1} \text{ or } \frac{24 \text{ gear on spindle.}}{24 \quad ,, \quad ,, \text{ plate.}}$$

The gearing is simple, therefore one idler is used and the plate revolves with the crank, thereby *losing* a division.

EXAMPLE—

Divisions required	= 41 (N).
Division plate selected	= 20 (H).
Holes to be indexed	= 20 (n).
Ratio of head	= 40 (V).

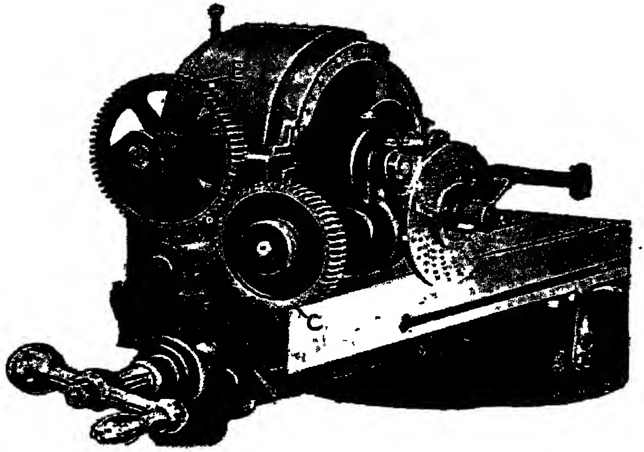


FIG. 17. SIMPLE TRAIN OF WHEELS SET FOR 271 DIVISIONS

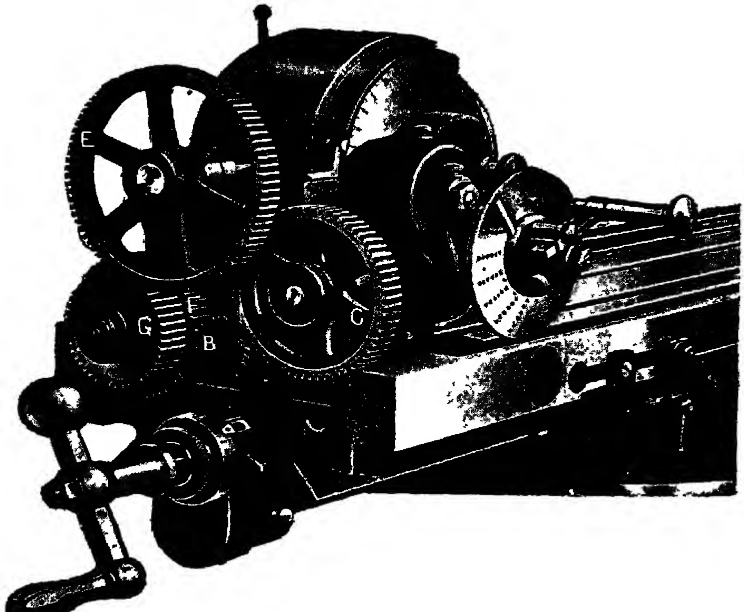


FIG. 18. COMPOUND TRAIN OF WHEELS SET FOR 319 DIVISIONS

In this instance HV is *less* than Nn, therefore the formula is set out as follows—

$$\frac{\left(\overset{\text{Division } N}{41} \times \overset{\text{Holes } n}{20}\right) - \left(\overset{\text{Plate } H}{20} \times \overset{\text{Head ratio } V}{40}\right)}{20 \text{ Plate } H} =$$

$$= \frac{820 - 800}{20} = \frac{20}{20} = \frac{1}{1} \text{ or } \frac{24 \text{ gear on spindle.}}{24 \;\;,, \;\;\;\; ,, \text{ plate.}}$$

Our rule says that as HV is less than Nn two idlers must be used, so revolving the plate against the crank and *gaining* a division.

Figs. 17 and 18 show simple and compound gearing respectively. The first is set for 271 divisions, the wheels being: $C = 56$ teeth; $E = 72$ teeth; $D =$ idler. It will be clearly seen that the idler is simply to rotate the division plate in the same direction as the crank.

Fig. 18 shows compound gearing set for 319 divisions. $C = 48$ teeth; $F = 64$ teeth; $G = 24$ teeth; $E = 72$ teeth; and $B = 24$ tooth idler.

When being used for differential indexing the head cannot be used at any angle other than 180 degrees (parallel to table) on account of the spindle gear being attached to the centre holding the work. The chuck may be used, but work cannot be passed through the hollow spindle, as the centre occupies that position.

SPIRAL MILLING

A further use of the differential head is to produce flutes or sides on cylindrical work that gradually perform a spiral on the work itself. This is carried out by attaching the head to the screw of the table by a train of wheels, so that the work revolves whilst the table is travelling under the cutter.

A toothed wheel of predetermined size is placed on the screw of the table behind the handle in place of a collar usually fitted when the head is not required. This wheel operates another wheel (with intermediates

inserted) attached to the division plate and revolves it. When the pin in the crank handle is inserted in the division plate, the plate drives the crank handle which in turn drives the job. From this it will be seen that, although geared, the head can be used as a simple dividing device just the same. On the machine being stopped, the pin can be withdrawn and the usual system of dividing proceeded with; also any division plate can be used. Such dividing is continually in practice when making taps, reamers, special cutters, spiral spur wheels, etc. The work can be held between centres or in the chuck, also the head can be set at any angle to the table on account of the arbor carrying the wheel that drives the division plate being parallel to the table and is in a fixed position. In *ordinary* practice no wheels are used on the "centre," as with differential dividing.

The lead screw of the table is $\frac{1}{4}$ in. pitch (four threads to the inch), therefore one turn of the screw will turn the head one-fortieth if wheels with an equal number of teeth be used as a train. It will, therefore, take 40 turns of the screw to revolve the head once, and, as the screw has four threads to the inch, the table will have travelled 10 in. This is the natural lead, and is called the "lead of the machine," and on this natural lead all spiral calculations are based. If the operator wishes to decrease the lead he speeds up the head so that it turns more quickly in proportion to the table movement; if he wishes to lengthen the lead, say, to 20 in., he slows down the head to one half.

According to the lead, so the angle at which the cutter is set to the work changes. This also applies to the diameter of the work, both having a distinct bearing on the angle. A graphic example of the relation of the lead and diameter to the angle is to cut a piece of paper as shown (Figs. 19 and 19A). The sides *B* and *C* are at

right angles. The length of C represents the lead to be cut, and the length of the side B represents the circumference of the job. (The length of A does not matter.) If the paper is now cut into a right-angled triangle using the outer ends of C and B, the side A will form the line the cutter will take in cutting the spiral, and

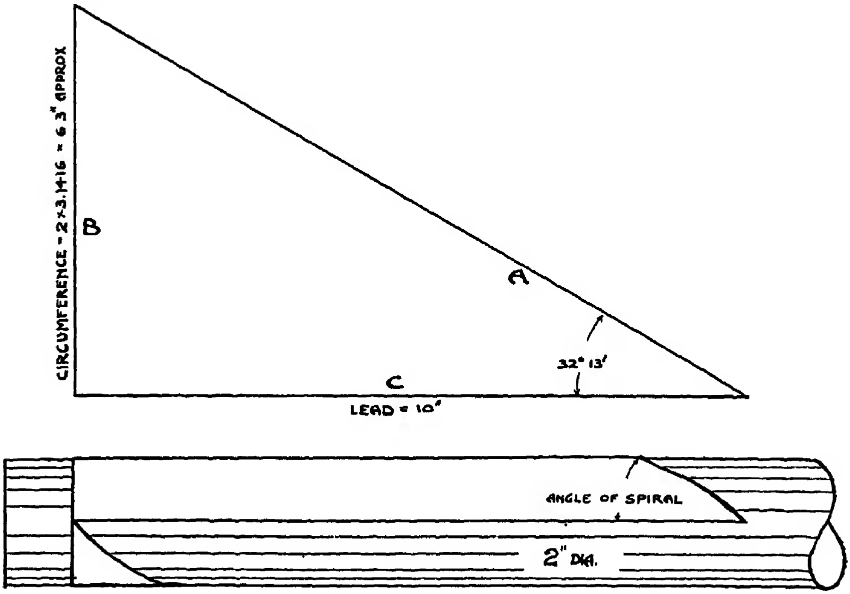


FIG. 19. PRACTICAL ILLUSTRATION OF RELATION BETWEEN LEAD AND DIAMETER TO ANGLE

the angle between A and C will be the angle at which the job must be set in relation to the cutter. The situation is clearly shown if the triangular piece of paper is laid around the job as in the illustration.

Without complicating the issue by small figures or fractional leads, let two pieces of paper be cut dealing with the natural lead of the machine, viz., 10 in., but using two different diameters of 2 and 4 in. respectively. Using approximate figures only, one triangle has the side B twice as long as the other.

First Triangle (Fig. 19) :

Diameter of job = 2 in.
Length of C = 10 in. (lead of spiral).
,, B = 6·3 in. (circumference of job).
Angle $C - A$ = 32 deg. 13 min. (angle of spiral).

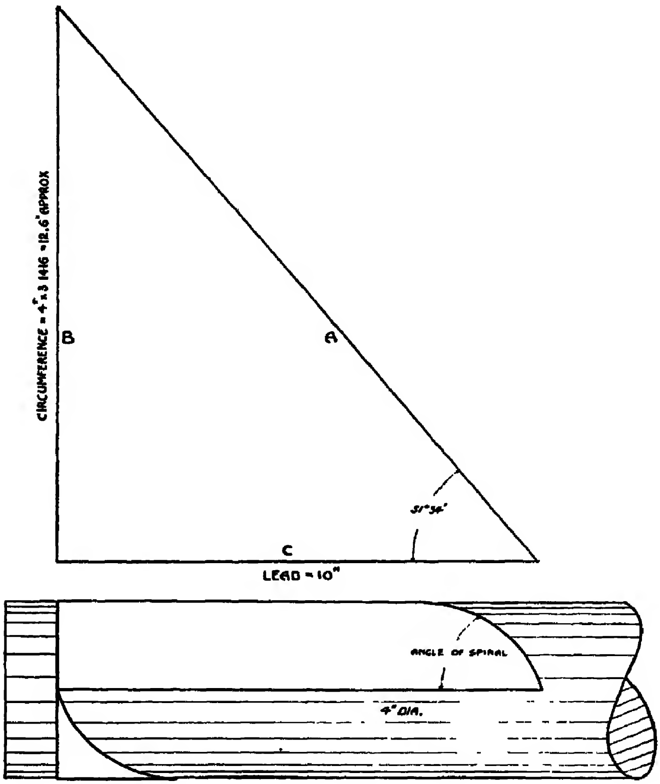


FIG. 19A

Second Triangle (Fig. 19A) :

Diameter of job = 4 in.
Length of C = 10 in. (lead of spiral).
,, B = 12·6 in. (circumference of job).
Angle $C - A$ = 51 deg. 34 min. (angle of spiral).

It is assumed the operator is versed in the solution of right-angled triangles and knows the way to arrive at the angles herein mentioned; anyhow, it is necessary to find the tangent of the angle between C and A by dividing the length B by C, the result being the tangent of the angle. On reference to a set of tables on trigonometric functions one finds the correct value of the angle, there being no necessity to find the length of A.

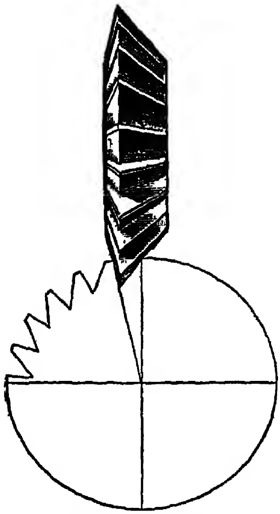


FIG. 20. CUTTER OFFSET MILLING REAMER

Tangent $A - C = B \div C$ (when one angle is 90 deg.)

$$= \frac{6{\cdot}3}{10} = {\cdot}63.$$

The tangent is therefore ·63.

The tables show that ·63014 is approximately 32 degrees 13 min. This is quite near enough for all practical purposes.

It is again pointed out that the operator must study arithmetic if he wishes to be a successful milling machinist. Nearly every job is preceded by a calculation of some kind.

The machine table is now turned to the degree required, or if the machine is not of the universal type, the head is swivelled around to the required angle, this head being a special attachment to convert the plain to a universal machine.

Care must be taken that the cutter is central with the work before proceeding, or the centre located so that the correct offset can be made (Fig. 20). Set the cutter in motion and raise the job until the cutter just scrapes the top and pass the table in all directions under the cutter. The spot made by the revolving cutter

will be on the centre line of the job. This is an easy method when cutting ordinary spur teeth, because the cutter itself can always be used to prove position.

With plain milling the job is often reversed without lowering away from the cutter and does not matter with straight flat surfaces, but with all spiral work the cutter must be free before an attempt is made to set for the next cut.

The majority of spirals are right-handed, but left-hand spirals are cut by swinging the table on the opposite side of the zero line and introducing an intermediate wheel extra to usual train to reverse the action.

The set of gears mentioned in the chapter on Differential Indexing are used to obtain the various leads, and Messrs. Brown & Sharpe issue a book with all machines giving full particulars of trains of wheels and angles from a lead of ·677 in to 149·31 in.

The method of calculating the gearing required is as follows : Already it is known that the natural lead is 10 in., therefore one must find out the ratio of the lead required to the natural lead. Should the lead required be 12 in., then the ratio is 12 to 10, or by dividing the required lead by the natural lead (10) the result is the ratio in the same manner : $\frac{12}{10} = \frac{6}{5}$ or 1·2 ratio. Example—

What gears will be used to cut a lead of 27 in. ?

$$\frac{27}{10} = \frac{9}{5} \times \frac{3}{2} = \left(\frac{9}{5} \times \frac{8}{8}\right) \times \left(\frac{3}{2} \times \frac{16}{16}\right) = \frac{72}{40} \times \frac{48}{32}$$

It will be seen the principle is the same as with lathe wheels.

Another example, but with a lead of 12 in. :—

$$\frac{12}{10} = \frac{72 \times 32}{48 \times 40} = \frac{\text{wheel on worm} \times \text{wheel on stud 2}}{\text{wheel on screw} \times \text{wheel on stud 1}}$$

The 72 goes on the worm that drives the division plate; the 40 goes first on the stud and the 32 on the top on the same stud, whilst the 48 goes on the lead screw of the table. As with the lathe the train can be transposed. That is the 72 can be put on the stud (in the second position) and the 32 can be put on the worm.

In cutting the natural lead of the machine it is not possible to fit in wheels of equal teeth, therefore the process is carried out by using a nullifying train such as—

$$\frac{56 \times 24}{48 \times 48} = \frac{1344}{1344} = \frac{1}{1}$$

With very short leads, it is preferable to disengage the worm wheel and connect direct through the centre carrying the job, which centre is provided with an arbor to take the change wheels (as with differential indexing). This method reduces the natural lead by one-fortieth, because the worm is eliminated. Calculations are carried out by the formula—

$$\frac{\text{lead required}}{40}$$

To index when the worm is out of operation, the wheel on the centre must have such a number of teeth that they can be divided into the number of divisions required, by swinging the gear out of mesh and replacing again at the next required setting. If eight flutes are required and a 40 wheel is placed on the centre, it would mean placing the wheel in mesh again at every fifth tooth.

The head cannot be swivelled when the centre is used to carry a wheel.

Fig. 21 shows a train of wheels with and without an idler pinion.

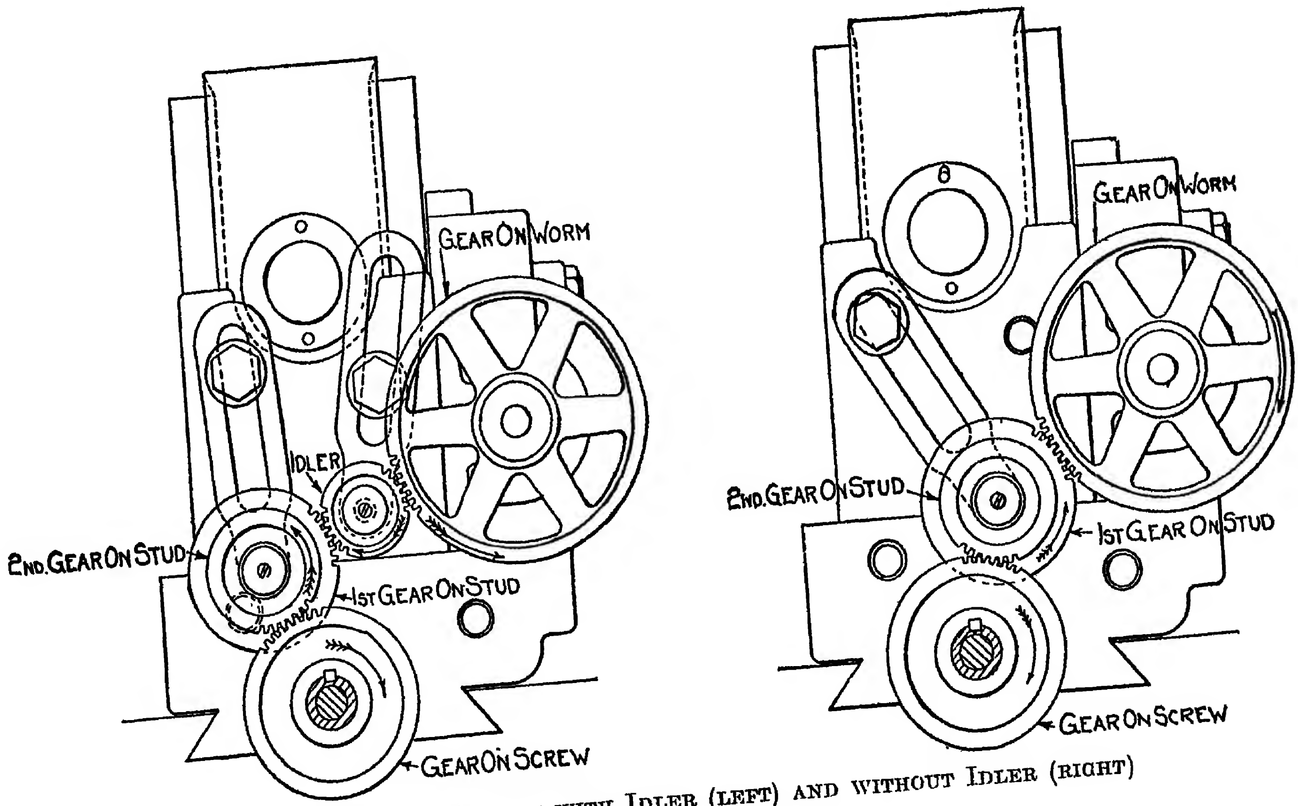


FIG. 21. TRAIN OF WHEELS WITH IDLER (LEFT) AND WITHOUT IDLER (RIGHT)

SETTING OUT AND MILLING CAMS

With the aid of the vertical milling attachment it is not only possible to mill cams, that at one time were laboriously made by hand, but to cut them with far greater accuracy.

The operation is carried out with the dividing head, which is geared to the machine table as in cutting spirals. The vertical spindle milling attachment is also used, and the two, being set to the correct angles, perform the task with great accuracy.

Cams are used on many machines and carry out many functions, their main job being to raise levers to a set position with a certain lift, perhaps to maintain that position for a period and then return the lever to its original place with quite another movement altogether. This means that at no time is the periphery of the cam concentric with its centre, unless movement of the lever is to be arrested or sustained in any particular position.

Owing to the great variety of lifts in use, wheels to bring about the various leads would be out of all economic proportion to general working. The usual change wheels are used in practice and leads of great accuracy obtained by setting the head and the cutter spindle at certain angles. It is with these angles that this chapter really deals.

To explain the method let a circular blank be fixed on the dividing head and the attachment and the head set in relation to one another as in Fig. 22A. Gear the head to the machine for a lead of 2 in. The cutter in use being an end-mill (only the sides of which are used), start the machine and, in one revolution of the head, the cutter will have cut into the blank 2 in. because the job will have advanced towards the cutter 2 in. during one revolution. Keep in mind the fact that

only the side of the cutter is used. Now let head and attachment be set as shown in Fig. 22B, and with a similar blank on the head, let the machine be started. The lead of 2 in. will take the job towards the cutter spindle, but the cutter will not remove any metal

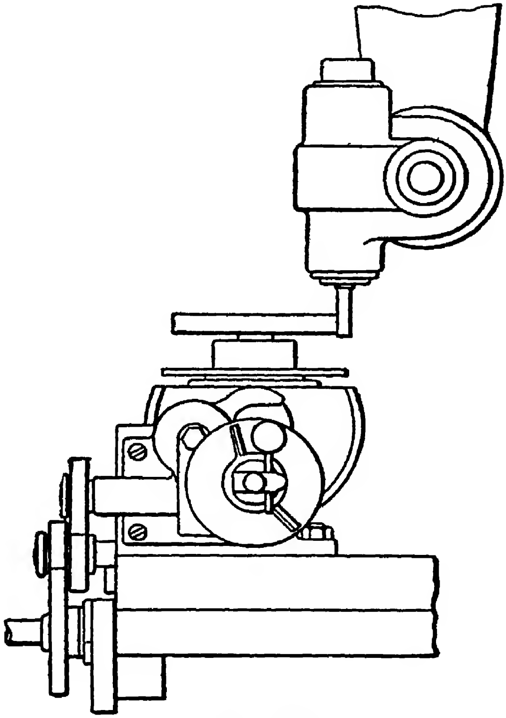


FIG. 22A

because the job does not get any nearer to the side of the cutter. At A the cutter cut in the maximum, and at B the cut was zero. From this it will be seen that by setting the head and spindle to some intermediate degree between 0 and 90 any particular lead can be obtained, as Fig. 22C.

The setting out of cams is quite a simple matter with practice and a knowledge of figures. For greater

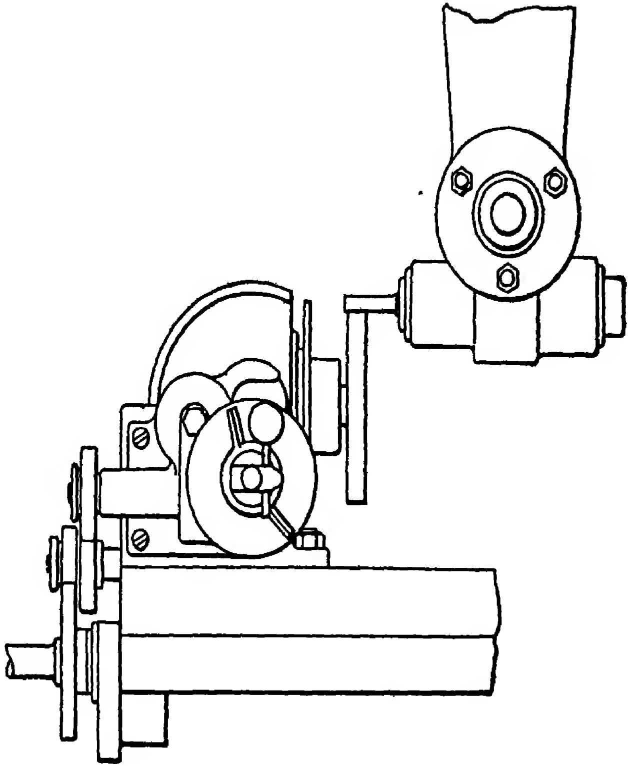


Fig. 22b

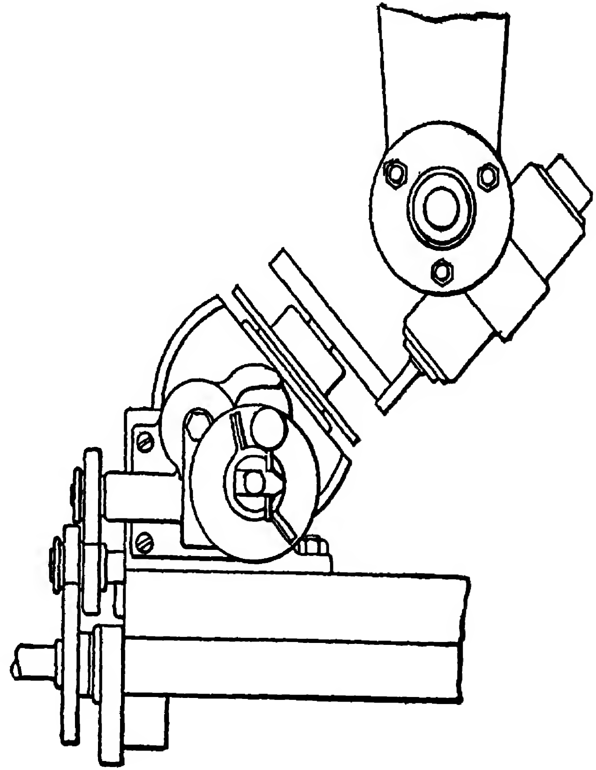


Fig. 22c

accuracy, first of all choose a lead nearest but larger than the lead desired to be cut, the reason being that the operator has the whole 90 degrees at his disposal

Fig. 23. Universal Attachment attached to "Plain" Milling Machine Cutting Spiral Spur Wheel

to attain finality. As an example it would be useless to put on wheels for a lead of 10 in. when a cam with a lead of 1·26 in. only is required. Choose a lead of, say,

1·302 in. (wheels 28–86–40–100) so that the 90 degrees range is spread over 1·302 in. only instead of over 10 in. The desired lead will then read in degrees and quarter-degrees instead of seconds. The reason for this soon becomes apparent to the operator.

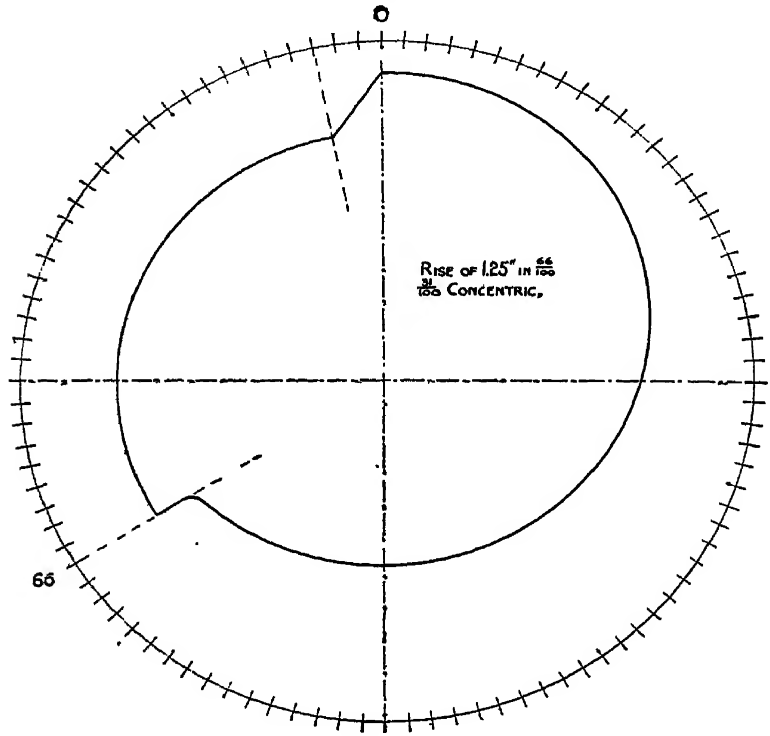


FIG. 24

For ease in cutting cams it is necessary to mark out the desired cam within a circle divided into hundredths. A 360 degrees circle can be used but it entails better draughtsmanship and time. In Fig. 24 is shown a cam with a rise of 1·25 in. in 66 hundredths of the circle. For the purpose of this article the concentric part can be ignored as it is produced by simply revolving the

head without moving the table. Also the portion from 97 to zero is filed up when machining is finished.

The operator must find the true lead for the whole circle, then the sine of the true and required leads, convert the sine into degrees, the answer being the

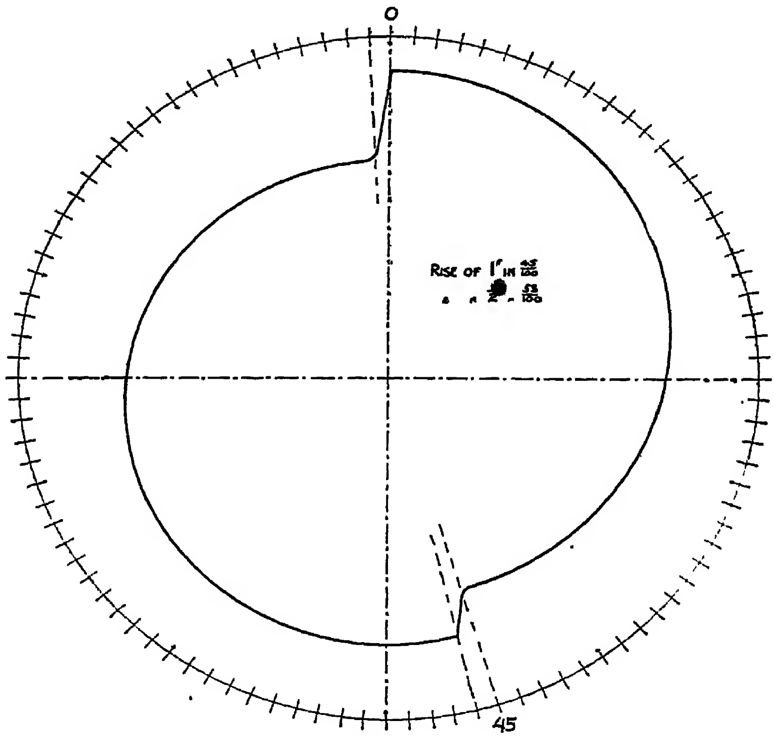


FIG. 25

angle at which to set the head. The cosine of the same answer is the angle at which to set the attachment.

Example with cam as in Fig. 24—

Cam to have rise of 1·25 in. in $\frac{66}{100}$. Find true or actual lead of whole circle.

$$\frac{\text{circle} \times \text{required lead}}{\text{portion of circle to be cut}} = \frac{100 \times 1{\cdot}25 \text{ in.}}{66} = \frac{125 \text{ in.}}{66}$$
$$= 1{\cdot}8939 \text{ in.}$$

Therefore the actual lead of the whole circle is 1·8939 in.

As already stated, choose a lead near the one required, say 2 in., then proceed as follows—

$$\frac{\text{required lead}}{\text{actual lead}} = \frac{1{\cdot}8939 \text{ in.}}{2 \text{ in.}} = {\cdot}94695.$$

Turning to a table on sines and cosines the nearest figure is ·94693 (approximately), the value of which is

$$94693 \begin{cases} \text{sine} = 71 \text{ deg.} -15 \text{ min. to which the head must be set.} \\ \text{cosine} = 18 \text{ deg}-45 \text{ min. to which the attachment must be set.} \end{cases}$$

Fig. 25 shows another cam with two different rises, i.e. 1 in. in 45 hundredths and $\frac{1}{2}$ in. in 53 hundredths.

In choosing the lead use a set of wheels for the larger of the two required leads, then without changing the train the head and cutter can be reset for the smaller lead.

Example with rise of 1 in. in 45 hundredths.

$$\frac{100 \times 1 \text{ in.}}{45} = \frac{100 \text{ in.}}{45} = \text{a required lead of } 2{\cdot}222 \text{ in.}$$

Wheels 24–40–24–72 give a lead of 2·222 in., therefore set both head and attachment vertically as shown in Fig. 24 and cutting commenced from the point desired.

Example with rise of $\frac{1}{2}$ in. in 53 hundredths (the other portion of same cam).

$$\frac{100 \times {\cdot}5 \text{ in.}}{53} = \frac{50 \text{ in.}}{53} = {\cdot}94149 \text{ in. required lead.}$$

The machine is already set to a lead of 2·222 in., therefore, again the procedure is—

$$\frac{\text{required lead}}{\text{actual lead}} = \frac{\cdot 94149 \text{ in.}}{2\cdot 222 \text{ in.}} = \cdot 42371.$$

The nearest figure in tables is ·42367 which is the sine of 25 deg.–4 min., at which to set the head, and the cosine of the same answer being 64 deg.–56 min. it is the angle to set the attachment.

Where much material has to be removed it is economy to drill the job to a rough outline and break away the portions not wanted.

To set out cams quickly a piece of sheet celluloid with a circle divided into 100 parts at which small holes are drilled is an expedient. Place the celluloid on the paper and at the sections of the circle desired place the point of the pencil through the hole or holes, then on removing the celluloid a line or lines can be drawn to the centre giving the exact sector desired. With this method there is no necessity to draw a circle and divide it into one hundred each time.

CUTTERS AND THEIR CARE

Frequent grinding is the best advice in keeping cutters fit. Letting them get blunt means the removal of too much metal to regain a keen edge, therefore do not let the edge go altogether before giving the cutter a touch up. Little and often is the best policy. A dull cutter wears more rapidly than a sharp one and consumes more power. Also, the surface of the work is indifferent.

Plain, side, and end-milling cutters are sharpened on the tops of the teeth *only*, whilst formed cutters are sharpened *only* on the faces of the teeth.

Clearance or relief of milling cutters is very important. This relief is the amount of material removed

from the top of the teeth back of the cutting edge to permit the teeth to clear the job and not to scrape over it after the cutting edge has done its work. On

FIG. 26. ANOTHER METHOD OF USING UNIVERSAL ATTACHMENT

formed cutters this relief or clearance has not to be considered, as the shape of the teeth are in relief when manufactured and sharpening only takes place on the face.

The angle of clearance somewhat depends on the diameter of the cutter and must be greater for small cutters. The diameter of the grinding wheel also has an

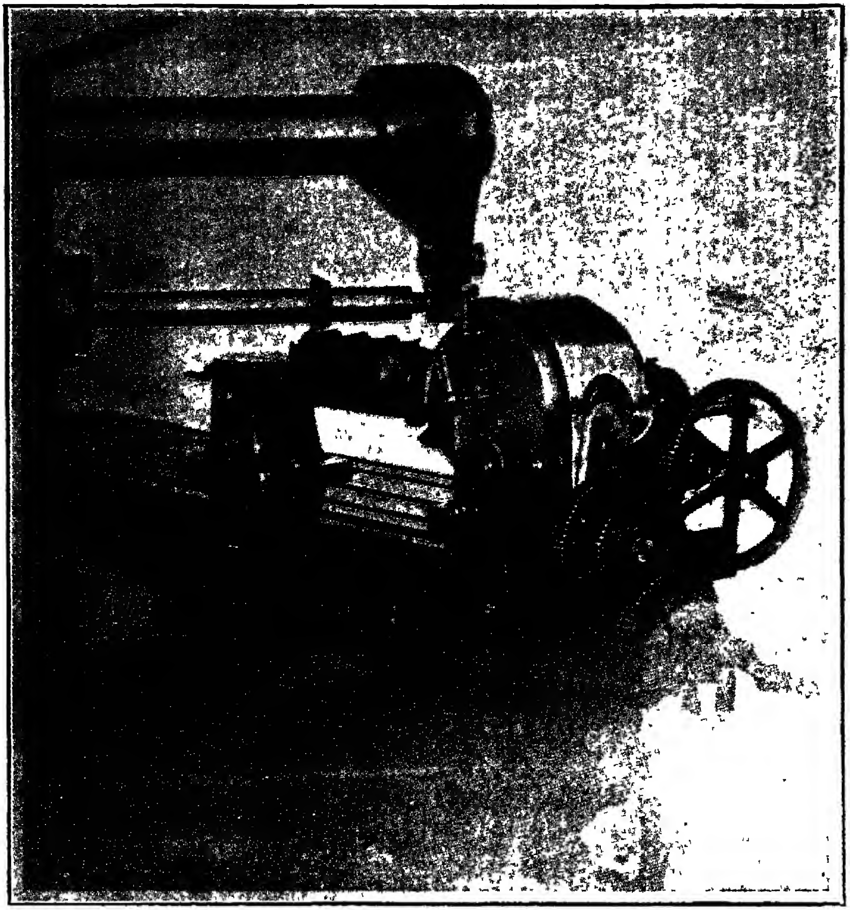


FIG. 27. MILLING SPIRAL CUTTER ON UNIVERSAL MACHINE

important effect on the clearance. The clearances should be from 5 to 7 degrees, and not more. The 7 degrees clearance being for cutters under 3 in. diameter. End-mills should have a clearance of

2 degrees, and it is as well to hollow the end somewhat so that the outer edges of the teeth will not drag. This

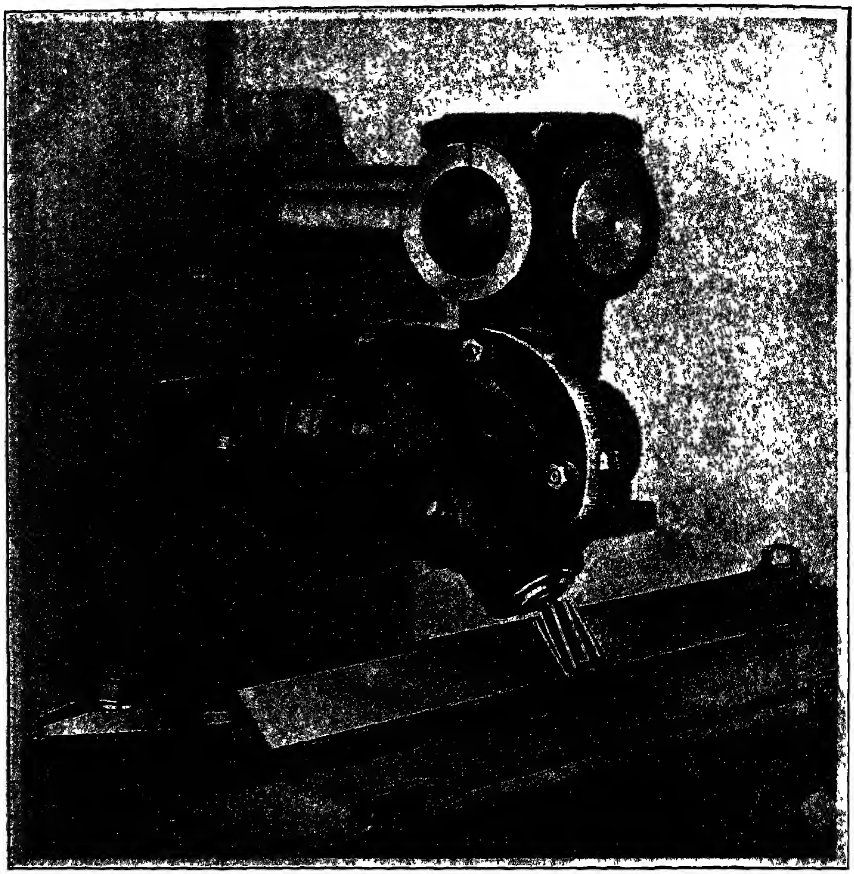


FIG. 28. ANOTHER USE FOR UNIVERSAL ATTACHMENT

is done by setting the swivel of the cutter when on the grinding machine slightly away from 90 degrees.

Vibration in cutters is set up by too much clearance, and the cutter should be re-ground with smaller clearance.

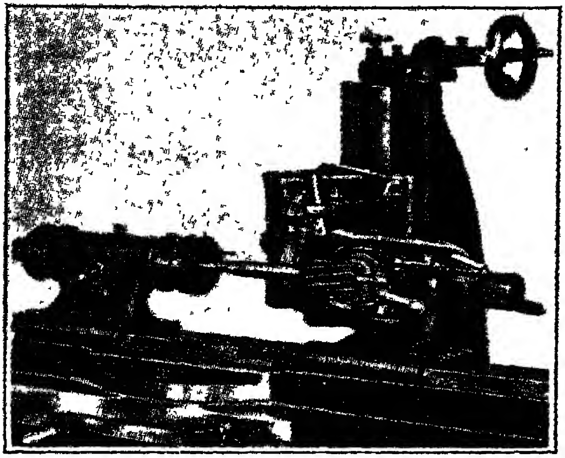


FIG. 29. GRINDING THE TEETH OF AN ANGULAR CUTTER

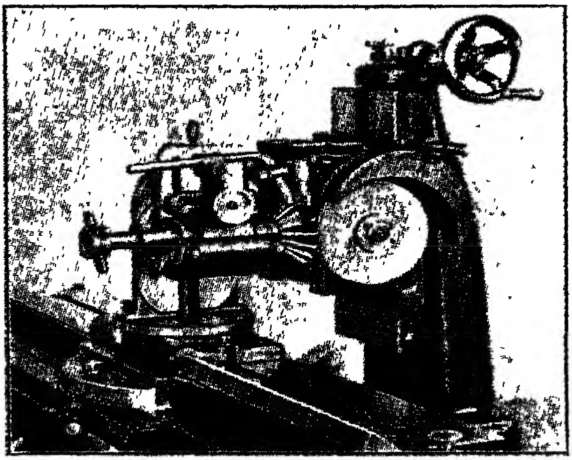


FIG. 30. GRINDING THE TEETH OF A SMALL SAW

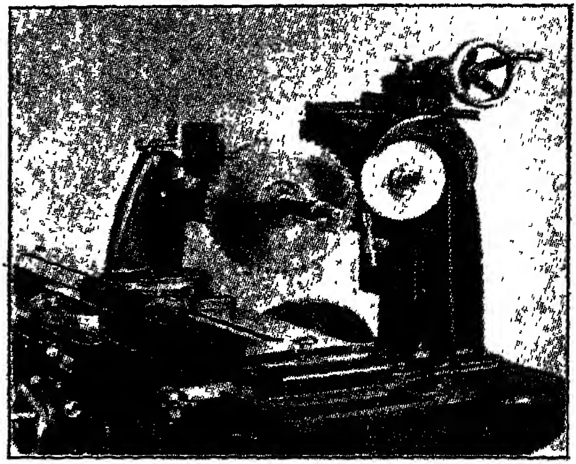


FIG. 31. GRINDING THE FACE TEETH OF A SPIRAL END MILL

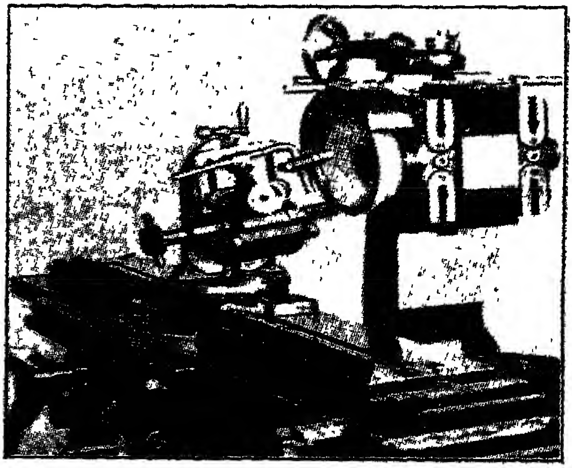


FIG. 32. GRINDING THE END TEETH OF A COARSE TOOTH END MILL

Sharpening with disc wheel		
Diameter of wheel	A 5 degree clearance	A 7 degrees clearance
in.	in.	in.
2	·093	·125
$2\frac{1}{4}$	·093	·140
$2\frac{1}{2}$	·109	·156
$2\frac{3}{4}$	·125	·171
3	·125	·187
$3\frac{1}{4}$	·140	·203
$3\frac{1}{2}$	·156	·218
$3\frac{3}{4}$	·156	·234
4	·171	·250
$4\frac{1}{4}$	·187	·265
$4\frac{1}{2}$	·203	·218
$4\frac{3}{4}$	·203	·296
5	·218	·312
$5\frac{1}{4}$	·234	·328
$5\frac{1}{2}$	·234	·343
$5\frac{3}{4}$	·250	·359
6	·265	·375

Sharpening with cup wheel		
Diameter of cutter	A 5 degrees clearance	A 7 degrees clearance
in.	in.	in.
$\frac{1}{4}$	·011	·015
$\frac{3}{8}$	·015	·022
$\frac{1}{2}$	·022	·030
$\frac{5}{8}$	·028	·037
$\frac{3}{4}$	·033	·045
$\frac{7}{8}$	·037	·052
1	·044	·060
$1\frac{1}{8}$	·050	·067
$1\frac{1}{4}$	·055	·075
$1\frac{1}{2}$	·066	·090
$1\frac{3}{4}$	·077	·105
2	·088	·120
$2\frac{1}{4}$	·099	·135
$2\frac{1}{2}$	·110	·150
$2\frac{3}{4}$	·121	·165
3	·132	·180
$3\frac{1}{4}$	·143	·195
$3\frac{1}{2}$	·154	·210
$3\frac{3}{4}$	·165	·225
4	·176	·240
$4\frac{1}{2}$	·198	·270
5	·220	·300
$5\frac{1}{2}$	·242	·330
6	·246	·360

The tables on this page will act as a guide to the operator in sharpening cutters with both disc and cup wheels. The cutter tooth rest shown in Fig. 33 is a piece of spring steel set vertically and moves with the grinding wheel so that the edge of the last tooth ground can be sprung over as the next tooth is set in position. If the wheel is revolved as at *C* then the grinding wheel will keep the cutter down on the edge

of the spring blade of the rest. If driven as at *B* a keener edge will be obtained without any burr, but the

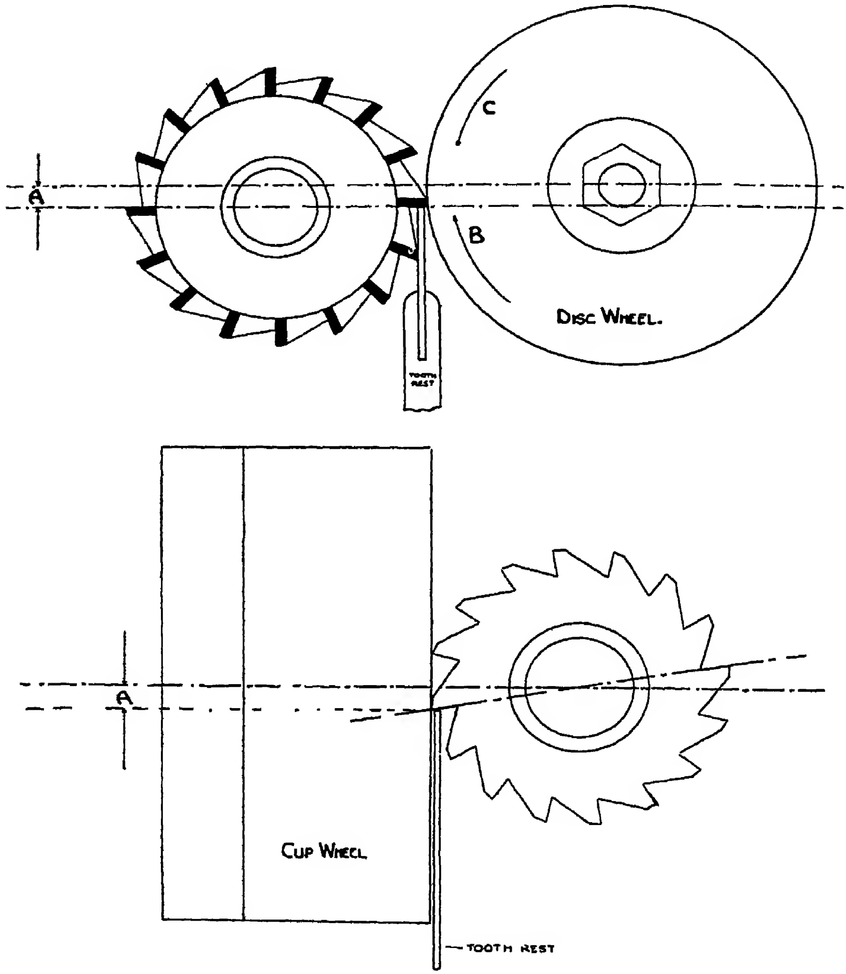


FIG. 33. USE OF CUTTER TOOTH REST

cutter will have to be held in position, otherwise the grinding wheel will lift the tooth from the blade and score it badly. It will be seen that when the grinding

wheel passes in front of spiral cutters the cutter also turns according to the lead of the spiral, therefore it is more simple to run the grinding wheel as in direction *C* when the wheel will automatically keep the cutter on the rest. Any burr formed should be removed with a small oilstone before any cutting is attempted.

Many large cutters have inserted teeth and the sketch explains method of withdrawing the wedges that hold

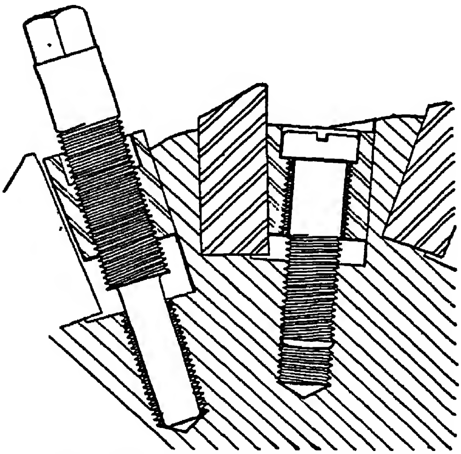


Fig. 34. Removing Inserted Tooth

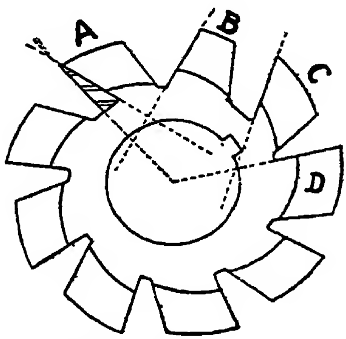


Fig. 35. Cutter Tooth Profiles

the teeth. Remove security screws and insert another that screws into the wedge and not the main body. This will extract the wedges and allow the teeth to fall out. Teeth are not removed for grinding, except when broken or there is a general replacement.

In sharpening all formed cutters care must be taken that the face of every tooth remains radial and the edges the same distance from the centre, otherwise the shape of the cutter changes and perhaps does no work. Any deviation from the correct method of grinding alters the shape and the cutter is no longer true to form. The tooth must not hook as it would if ground

as shown at *C*, Fig. 35, nor must it drag as it would if ground at *B*. At *A* is shown the tooth ground out of square which will produce an incorrect tooth (one side being different to the other) and have a tendency to push the job out of position. The correct sharpening

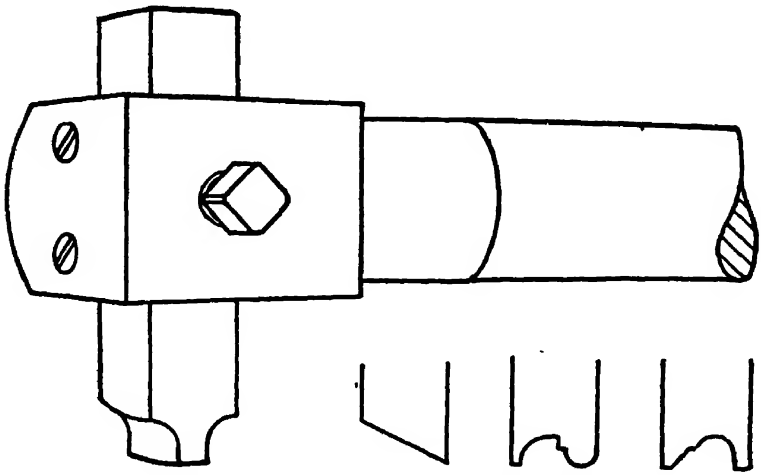


FIG. 36. SPECIAL TOOTH HOLDER

is shown at *D*, the grinding wheel being in line with the centre of the cutter.

The operator can also make up special cutters and fit them in a taper shanked holder (see Fig. 36). Many such cutters are made and should be stored for future use, as they are always handy and take up little space.

It will be seen that the milling machine is a very accurate measuring machine, and there seems no limit to its possibilities in that direction providing the lead screws are accurately made. This means the machine must be of high class quality. The cheap machine cannot produce good work however skilled the operator.

The author is indebted to Messrs. Buck and Hickman, Ltd., for many of the illustrations in the foregoing pages.

SECTION XX

JIGS AND TOOLS

BY

C. M. LINLEY

SECTION XX

JIGS AND TOOLS

INTRODUCTION

THE object to be aimed at in the production of what are known in mechanical engineering establishments as "jigs" and "tools" is to produce means whereby articles can be manufactured in numbers, by skilled and partly skilled labour, in such a manner that each article produced shall be alike and shall be interchangeable with others produced by the same jig or tool. The word "jig" is mostly applied to something connected with drilling, in the form of a plate or box, which is held firmly to the article being made, whilst one or many holes are drilled in it. The word "fixture" is of American origin, and is usually applied to something that is fixed to a machine, such as a specially formed piece to which can be attached parts that have already had a machining operation performed on them, so that it can be assured further operations are accurately carried out in relation to a previous operation. The making of fixtures comes within the accepted scope of "tool and jig-making."

The word "tool" in its relation to "tool-making," in the sense with which we are now dealing, does not include such tools as files, hammers, ordinary turning tools, standard sizes of drills or reamers, etc.

Broadly speaking, "tool," as made by the tool-maker in an engineer's shop, means something that cannot be bought ready made; something that has to be made for some special job. The class of mechanic usually employed on such work is, or should be, possessed of higher skill than the usual turner, fitter, or machine

hand, and should be able to work to a finer degree of accuracy than that required for general work. In large shops they are sometimes divided into tool turners, tool fitters, tool millers, and tool grinders, but in smaller shops they are often expected to be all-round men who can do anything, including hardening and case-hardening. They are supposed to own a better kit of personal tools than the rank and file of mechanics. It is essential that they should be able to read a drawing accurately, as without this they cannot hope to be successful.

THE FUNCTIONS OF JIGS AND FIXTURES

Before anyone can become useful in the tool room, (as that department of a works is called where tool and jig work is carried out), it is essential for him to grasp certain leading rules, which must never under any circumstances be departed from.

The first operation on any part being machined by means of jigs or fixtures is usually performed without the aid of a jig. As an example we will take a flange which has to be drilled with a number of holes at a certain distance from the centre and at even distances apart. Such an article would be turned first in a lathe, if it had a projecting spigot, or a bored recess, this would be used as a means of locating the jig used for drilling the holes. In the case of a flat plate with holes to be drilled in it, it would be first planed, without a jig. It would probably be planed on both sides and on one edge; this edge would probably be used to locate a jig for drilling the holes. Were such jigs as those described later, to be laid on a rough casting they could not be expected to lie evenly, and the holes in the jig would not be in axial alignment with the drill. Only in very rare instances is a rough casting or forging held in a jig for the first operation. When this is done, all

following operations must be located from the previous one, in no case should an article be held by an unmachined part a second time, further operations must in all cases be carried out by a location from some previous machining. The same rule applies to fixtures. As an instance, a plate might be fixed to a lathe chuck, bored to receive the spigot of a flange which had been machined on one side, whilst further operations are being carried out on the opposite side. Such a plate might be called a "fixture." A fixture for a milling or planing machine should be made so that some previously machined face of the work can be fixed to it whilst further milling or planing is carried out, but in no case, where articles that have had machining done to them, should they be held by a rough unmachined surface on a fixture.

JIG- AND TOOL-MAKING

In Large Establishments where Jig and Tool Draughtsmen are Employed. In the larger engineering establishments a special drawing office is provided, where all jigs and tools are drawn by a special staff of draughtsmen. In such establishments, the task of the tool-maker is a comparatively simple one, as all dimensions are carefully set down for him, all materials to be used are mentioned and limits of accuracy given. The work of the tool-maker in such an instance is little more than that of a high-class fitter, turner, or machine operator, as he has no designing or scheming to do. So long as he carries out the instructions set down, the success or failure of the jig or tool rests with its draughtsman.

Where No Jig and Tool Draughtsman is Employed. In a small establishment, a tool-maker may have a piece of work given to him and be told to make the necessary tools, jigs, and fixtures for its production. In such a case his task is more difficult—he must be able to design

the necessary appliances. He must take the piece of work and consider what operation should be done first. He must then see his way clear so that he can locate the work from this first operated upon part, so that the next important part of the machining can be done in exact relation to what has been done before, and follow on with further operations until the part is finished.

It is our intention, as far as possible, to give instructions that will enable the reader to carry out jig- and tool-making of this description, as in many instances, the judgment of a really good and experienced tool-maker will produce better results than when all is set down for him by draughtsmen, who in many cases are wanting in shop experience.

To carry out tool-making of this description, a knowledge of drawing is essential.

OUTFIT FOR JIG- AND TOOL-MAKING

Any one who aspires to be classed as a tool-maker should have a kit of personal tools of a more complete kind than that used by an ordinary fitter or turner. Beyond the usual set of callipers, squares, etc., which all mechanics are supposed to own, the following kit is suggested as the personal outfit of a tool-maker—

1 in. micrometer.
A complete set of Starrett's, or other make, combination square and protractor.
A dial test indicator with full set of accessories.
A sliding gauge.
A piece of sulphate of copper, and some Prussian blue.

Where high-class tool-making has to be done, it is essential that certain things should be provided by the firm. In cases where the firm will not supply the necessary outfit, it is wise for the tool-maker to make an application for what is necessary, and if he is not

provided with what he requires, to point out that the work cannot be expected to be of the highest standard.

THE EVILS OF POOR EQUIPMENT IN THE TOOL ROOM

The writer is sorry to say that there has been a tendency in this country to stint the tool room so far as equipment is concerned. It is true that the tool room is in a way non-productive, that is to say, what is produced there is not sold, whilst what is produced in the shops represents immediate money. A short-sighted view of these bare facts, without going beyond them, has in the past done incalculable harm to British engineering, not only in the matter of the cost of production, but in the accuracy of the work produced.

The tool department, its equipment, and its personnel, should not be looked upon as a necessary evil, but as the place that can save more money for a firm than any other department. A tool department that is expected to make bricks without straw should protest, loud and often, until it gets a proper equipment. The following list of accessories may be looked upon by some as an extravagance, but the view of the writer is that it is the barest equipment with which a department can be expected to make proper tools and jigs.

Besides the necessary equipment of tool room lathes, milling machines, drilling machines, and the full equipment of grinding machines, the following tools should be provided.

Chucks. Taylor chucks should be fitted to all lathes, as they are the only chucks suited to tool-making. Four-jaw chucks should be provided, as well as a drill chuck fitted to the poppet.

No matter how good the equipment of the tool room, it will soon become more or less inefficient unless it is properly looked after. It is essential that a tool room

should be dry, that is to say, that the atmosphere should not be one that will cause all tools to rust unduly. A good tool-room equipment is as follows—

Large lining-off table.
Surface plates.
Straight-edges.
Long rules.
Large sliding gauge of first-class make.
Micrometers, above 1 in.
Height gauge of first-class make.
Depth gauges.
Scribing block with test indicator.
Adjustable parallels, Starrett's No. 154, two pairs.
Twist drill and wire gauges.
Tool-maker's clamps.
"V" blocks, assorted.
Angle plates, assorted.
Centre tester, Starrett's No. 65.
Test indicator, Starret's No. 196.
Taylor's machine vices.
Buttons for locating holes, Brown and Sharp's full set, long and short.
Morse taper gauges.
Johansson gauges.

The best way that the writer has found of keeping the equipment of a tool room so that it can be got at instantly when required, is to have cupboards made which are shallow, just deep enough for the appliances to stand side by side on the shelves.

Glass doors to the cupboards are convenient, as the articles can be seen, and time saved when they are wanted. The writer has, however, found that fine-mesh wire or expanded metal makes the best door, as the articles can be locked up when not in use, and at the same time they are always visible.

ESSENTIAL FEATURES IN JIG-MAKING

Unless the following points are strictly observed, no drilling jig will be entirely successful. Ignorance or disregard of these features is the cause of much scrapped work and friction between the drawing office and the tool room. It is true that a tool-maker is supposed to follow any drawings given to him from the jig and tool draughtsman, but if a drawing of a jig is handed to the tool room which does not conform to the following rules, it is best to call attention to the fact, and if the draughtsman persists, to make the jig under protest.

(*a*) It is necessary that any article held in a jig, to be drilled or otherwise operated upon, should be gripped so that it cannot move whilst the operation is in progress, otherwise the work will not be accurate. Recognizing this, many will arrange clamps, set-screws, etc., which although they may hold the work well enough, may distort it so much that when the holding is released the work will spring back to its original form, with the result that all accuracy is lost. It is essential that where

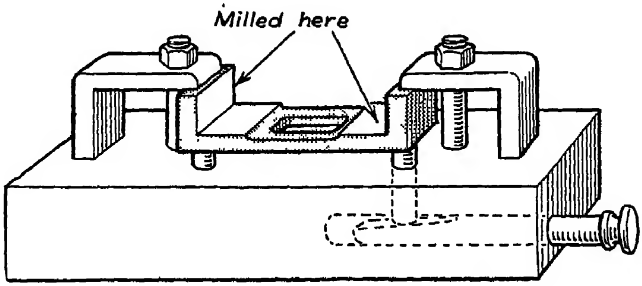


FIG. 1. SELF-ADJUSTING ABUTMENT

any piece of work is held by a clamp or a set-screw there should be an abutment opposite the holding. Wherever possible, three points of bearing are preferable to four, especially when holding rough castings for a first operation. There are, however, cases where four-point bearing surfaces have to be provided—three of these may be fixed points, but one must be adjustable, as shown in Fig. 1, where we see a typical self-adjusting abutment. To emphasize this point, we repeat that no clamp or holding device should distort the work being operated upon whilst being held in a jig.

(*b*) It must be easy to clean all chips from jigs, which must accumulate in all machining operations. It is obvious that where a chip is allowed to lie between the jig and any part of the work which is used as a locating point, errors must occur. It may be said that the

operator should clean his jig thoroughly before placing a new piece of work in it, but it should be remembered that jigs are given to persons of little skill to use, so such persons cannot always be relied upon to carry out the cleaning thoroughly. The examples shown in Fig. 2 show how jigs should be made, so far as the points against which the work rests for accurate location.

Where jigs have to rest on the table of a drilling

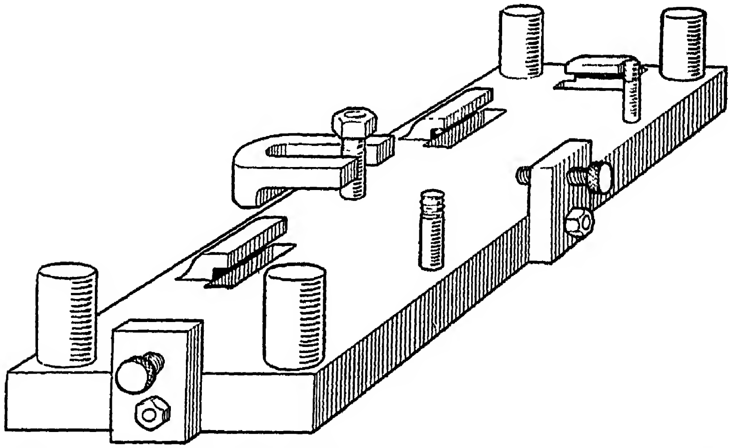


Fig. 2. Jig, with Provision for Chips to be Cleared Away

machine, it is not wise to provide a large, flat surface for the jig where it lies on the table. The reason for this is that chips are not easy to clear from under large flat surfaces, consequently an operator may lie his jig down on a lot of chips, in which case all accuracy is lost. Feet should be provided as shown in Fig. 3, as these, if moved about on the table, will push all chips aside and come down to the true surface. It is well when making a jig that is to be used on a machine that has slots in the table, to be sure that these feet are wider than the slots, otherwise they will be continually dropping into them. To emphasize this point, we

repeat that all jigs should be easily cleaned from chips, and that all locating points should stand proud of all surrounding surfaces, and that all corners where chips can lodge should be avoided.

(*c*) Although it is essential that all drilling jigs should be so arranged that the bush which guides the drill should come as near to the work as possible, it is necessary, especially where large drills are used for steel

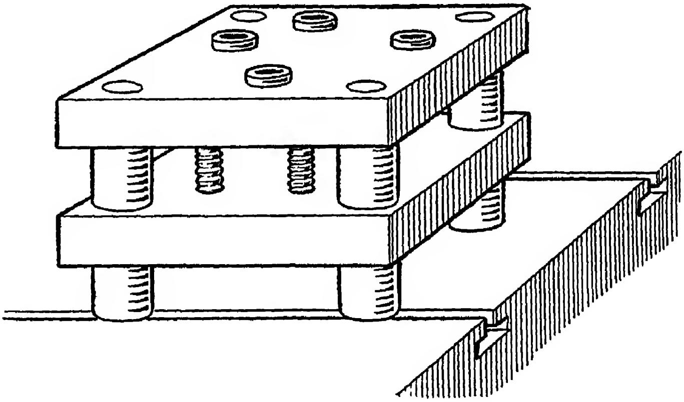


FIG. 3. JIG TABLE WITH FEET

work, to provide ample means for the chips to escape. For this reason, it is often found an advantage to make the hardened bush which guides the drill, so that when the drill has found a good bearing in the work, the bush can be removed. By this means the damage and wear to the bush caused by the strong chips, produced by modern high-speed drills, can be avoided. Another reason for the easy removal of the bush is that lubricant or coolant can more easily find its way to the drill, the enlarged hole previously occupied by the bush forming a funnel.

To emphasize this point, we repeat that means should be provided for the escape of chips and for the introduction of coolant.

CASTINGS PREFERABLE FOR JIG-MAKING

Some tool-makers will go to a lot of trouble to make up jigs from pieces of wrought steel instead of having a pattern and a casting made. Experience has shown that a pattern and casting is in most cases the most satisfactory and the easiest way of constructing a jig. With a pattern, one can get exactly what is wanted in the way of bosses and other forms all solid with each other, whilst with a jig that is built up of parts of wrought

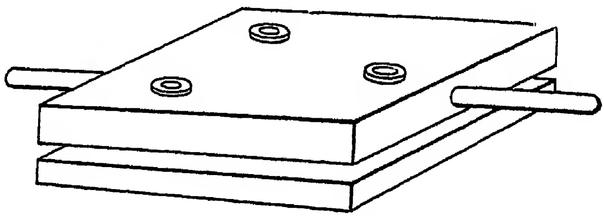


FIG. 4. JIG PROVIDED WITH HANDLES

steel there is always the likelihood of parts becoming loose, and errors occurring.

When making patterns and castings for jigs that have to be handled, it is best to see that there is no unnecessary weight, otherwise the jig is not a convenient one for a man to work. Jigs that have to be used on an ordinary drilling machine should have their feet of such a size that they do not drop into the slots usually found in the tables of such machines. This point can be disregarded in the case of jigs that are to be used in radial drilling machines, as in such cases the jig can be bolted down and the drill moved from hole to hole.

Jigs that have to be turned over for the drilling of holes on both sides of the work, or for discharging the work, should have handles fitted, as shown in Fig. 4, so that they can be easily manipulated. For large size jigs, a sling should be provided, as shown in Fig. 5, so that the jig can be lifted by a tackle and turned over.

BACK FACING TOOL FOR USE IN DRILLING MACHINES

There are cases where the face of a boss may require machining on the underneath side as it lies upon the table of the drilling machine. In smaller work it is usual to turn the job over and to face all bosses with the

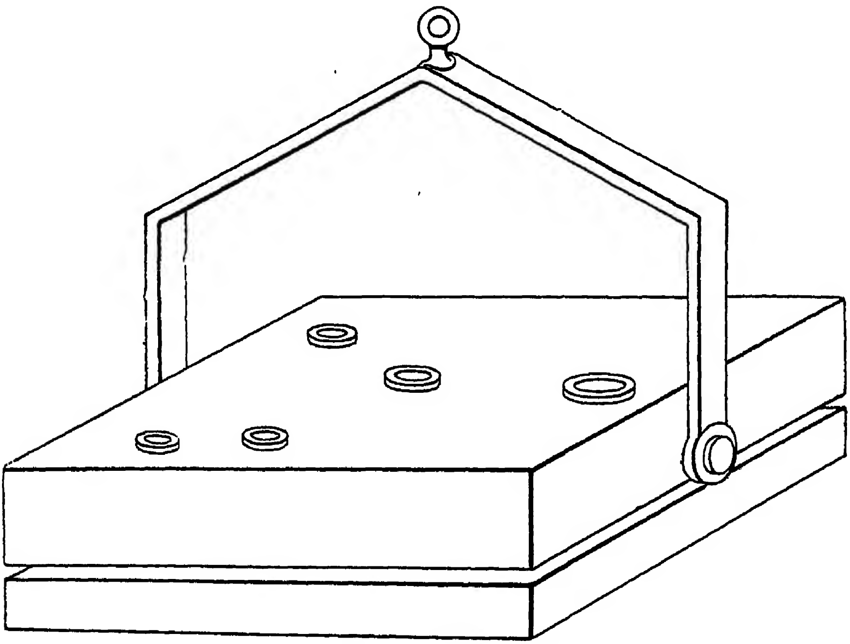


FIG. 5. HEAVY TYPE METAL JIG, PROVIDED WITH A SLING FOR PORTABILITY

usual tool provided for that purpose, but in large work it is found more economical to do such facing whilst the job is in place.

There are several ways of making such tools, and such tools can be bought ready made. The type shown in Fig. 7 is a very simple form, and affords a good drive for the cutter. The lower end of the shank should be

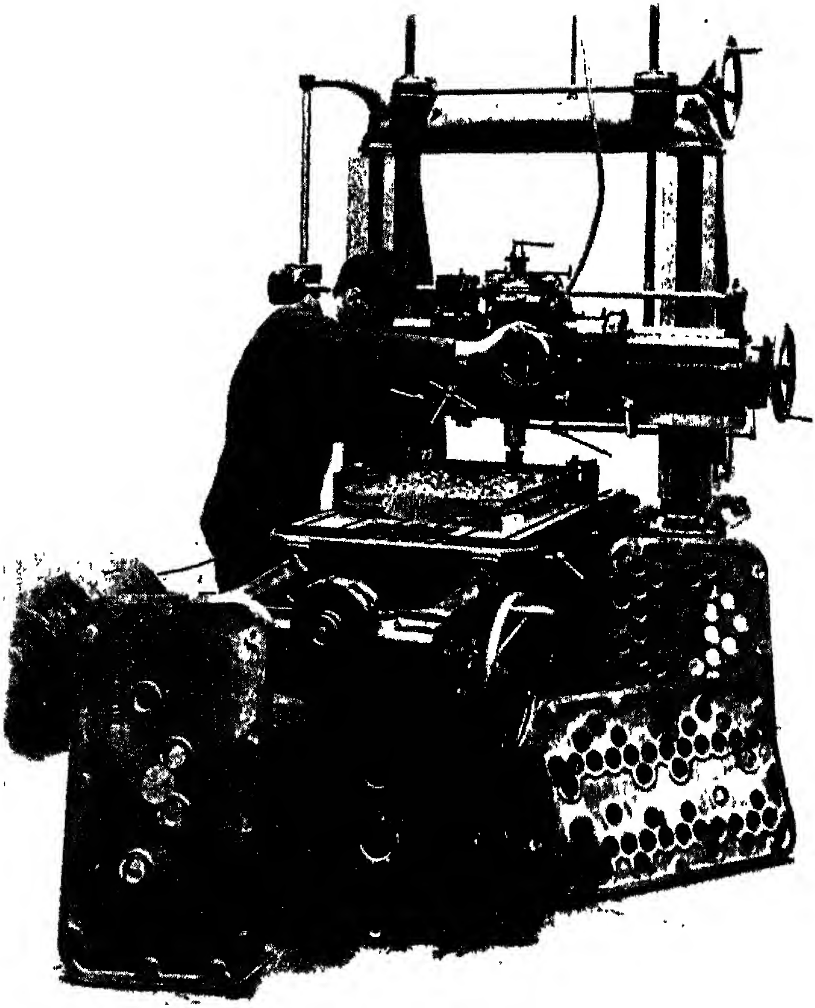
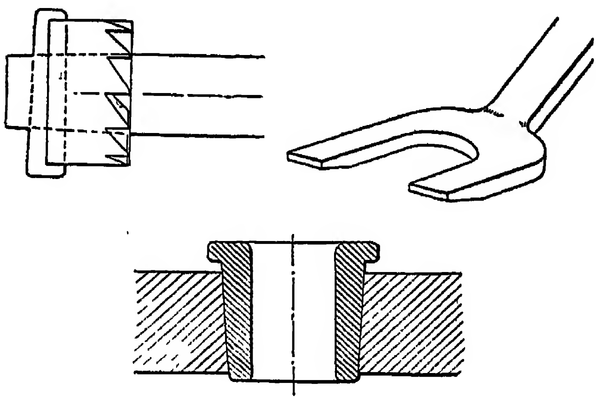


FIG. 6. "SWISS JIG BORER" IN OPERATION

tapered to receive the cutter, which is held up and driven by a cottar. The upper end of the shank is best left parallel so that it can be held in a chuck, as with a taper shank there would be no means of pulling the cutter upwards.

REMOVABLE BUSHES FOR DRILLING JIGS

It has already been pointed out that in certain cases it is advisable to remove the bushes of drilling jigs when once a drill has entered below its chamfer. This is



Figs. 7–9. Back Facing Tool and Bush Remover

particularly the case when drilling steel, as the strong chips produced by modern drills cause undue wear in the bushes and obstruct the stream of coolant.

There are several plans adopted for the easy removal of such bushes, some preferring to screw the bushes into their holes, whilst others rely on a slight taper, with a flange on the bush which can be lifted by means of a forked pinch bar, as shown in Fig. 9. The latter plan is preferable, as the taper can easily be cleaned from chips, whilst the screw is more difficult to keep clear, and chips are likely to throw the bush out of centre.

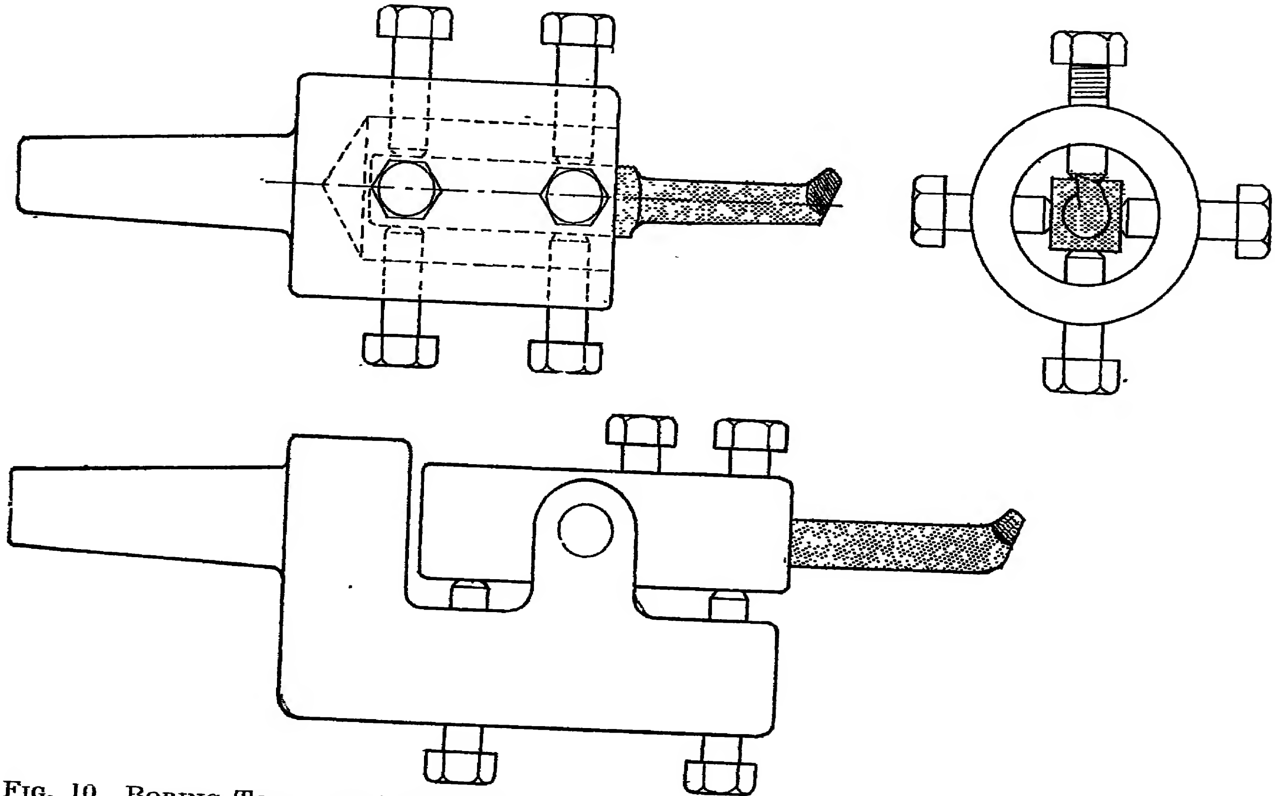


Fig. 10. Boring Tool for Correcting Position of Holes in Drilling Jigs, for Use in a Milling Machine

ACCURATELY POSITIONING HOLES IN DRILLING JIGS

Those who aspire to be tool-makers, must abandon all ideas of locating the positions of holes in drilling jigs by means of measurements taken from a rule with dividers (location by means of centre punch dots with circles scribed round them) as such methods, although good enough for many ordinary jobs, are practically never used by up-to-date tool-makers. Some means must be adopted whereby the positions of the holes in relation with each other, or in relation with some guiding part such as the spigot of a flange, or their distance from the edge of some part that has been planed, can be carried out with more accuracy than is possible with scribed lines and punch dots.

MAKING DRILLING JIGS IN THE MILLING MACHINE

One of the commonest ways of making drilling jigs for such holes as those through which bolts are to pass, and where a certain amount of clearance can be permitted between the bolts and their holes, is to locate the holes roughly by scribing them off in some cases, then clamping the jig to the table of an ordinary milling machine, and by means of the indexed screws bring the jig to such positions as are necessary for the more accurate boring of the holes by means of a single-pointed boring tool held in a holder such as those shown in Fig. 10. By moving the long slide to the required distances as shown on the index of the screw, and by raising or lowering the table, the required dimensions can be obtained with a degree of accuracy that is good enough for most ordinary engineering work.

When this method is adopted, great care must be taken to avoid errors that may occur through backlash in the screws. When reading the index, the screw

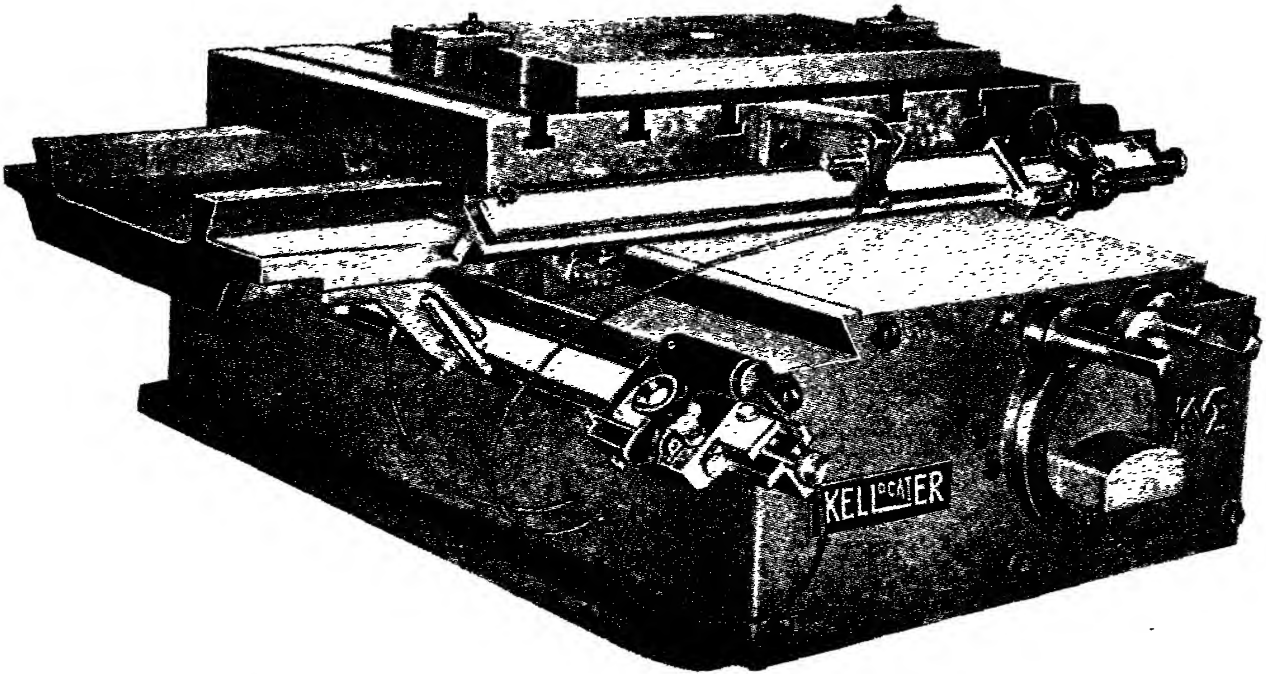


FIG. 11. THE "KELLOCATER" JIG BORER ATTACHMENT

This device enables a drill press to be converted into an efficient jig borer without alteration to the machine itself. It is entirely self-contained, and the unit is simply clamped to the table and may be readily removed when it is desired to leave the press free for its normal functions. Little skill is required in operating the "Kellocater," and it gives an amazing degree of accuracy. It is made by the Keller Mechanical Engineering Corporation, Brooklyn, N.Y., U.S.A.

should always be moving in one direction, as a partial reversal of the screw may bring the index to the required position, but owing to backlash, which is present in all slide screws, a false reading may result in a serious error.

Whilst using the boring tool shown in Fig. 10, care should be taken that a sufficient number of light cuts are made to ensure that the bored hole shall not be effected by any error that may have existed in the position of the preliminary hole that has been drilled in the jig. The exact diameter of holes bored in this manner can be obtained by using a reamer in the milling machine to finish the hole with.

SPECIAL JIG-BORING MACHINES AND APPLIANCES

Various appliances, such as tables with indexed screws, are made for the production of drilling jigs, an example of which is shown in Fig. 11 in the "Kellocater." Such appliances are said to be of use in an ordinary drilling machine; the writer's experience is that ordinary drilling machines are not made for accurate work so far as the fit of the spindle in the bearing nearest the work is concerned, consequently any slackness here may result in errors in the jig produced. Such appliances are, however, quite useful when used in a vertical milling machine, where a reliable fit of the spindle to its bearing can be relied upon. Such appliances are more useful when they are fitted with a revolving table, which can be used for such holes as those of cylinder covers, etc.

In all probability, the "Swiss Jig Borer" (see Fig. 6) made by the Société Genevoise d'Instruments de Physique, of Geneva, is the last word in precision jig-boring machines. Not only will this machine produce work of the greatest possible accuracy, but it produces it quickly and cheaply. To ensure a greater degree of

accuracy than can be relied upon with screws, all screws are fitted with a means of correcting local or other errors, the plan adopted being that known as the "mountain range," which is described later.

Another, and most useful machine for jig boring, is that made by the Cochran-Bly Company, of Rochester, U.S.A. This machine is provided with universal slides

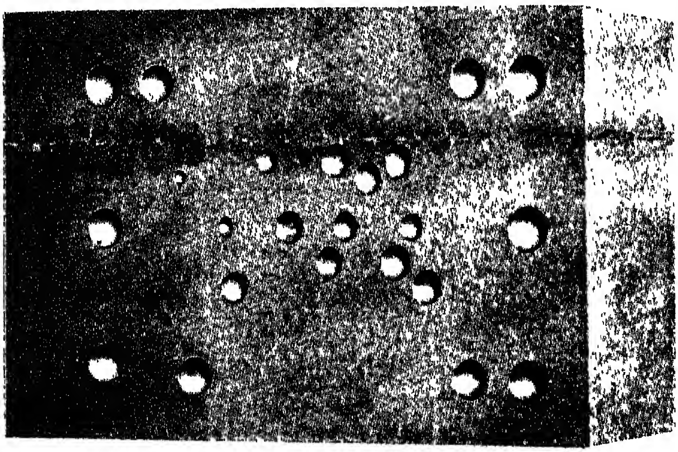


FIG. 12. TYPICAL JOB PERFORMED ON "KELLOCATER"

and a circular motion, all of which are accurately indexed. A spindle such as used in a vertical boring or milling machine is fitted for drilling, boring, or milling. By the side of this is a ram of a slotting machine. This is adjustable to work at any angle. By the use of this machine, jigs can be drilled, bored for accuracy, slotted, vertically milled, and vertically shaped, all in the one setting, and all dimensions determined by the indexed screws. Where press tools have to be made, this machine is of great value, as the taper or draught necessary on press tools can be slotted out, and practically the whole press tool made in the one setting.

The Button Method. Where a high degree of accuracy is needed and no special jig-boring machines are installed, the button method is perhaps the most reliable. Fig. 13 shows the kind of button which is made for this work. They are of hardened steel, ground on the outside to accurate dimensions, so that the position of the holes they represent can be relied upon. Their faces are ground truly, so that they can be counted on to stand perpendicular with any face to which they are temporarily attached. Wherever there is to be a hole in a

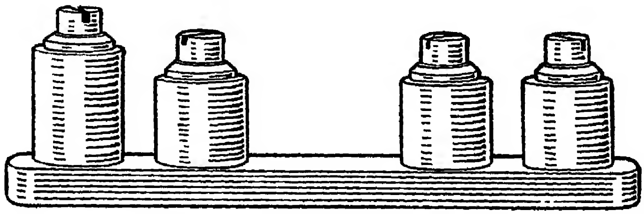


FIG. 13. VARIOUS BUTTONS

drilling jig, one of these buttons is held in position by a hole drilled and tapped to receive a small screw. These screws do not fit the holes in the buttons, so the latter can be shifted about until an accurate position is arrived at, then the screw is tightened, and by means of its washer it holds the button temporarily in its position.

If Johansson gauges are available, they can be used to separate the buttons or to determine their distance from a machined edge of a jig. Should Johansson gauges not be available, discs can be turned from thin plate to the exact distance which should separate the buttons or otherwise locate them. Straight-edges can be employed where buttons have to be arranged in a straight row. When all buttons are satisfactorily in place, the jig can then be bolted to the face plate of a lathe as shown in Fig. 14. The first button to be set true is then located by means of the test indicator; care

must then be taken that the jig is properly tightened on the face plate, and a last trial made with the indicator to make sure that the final tightening has not shifted it. The button can now be removed and the hole bored. This can be repeated until all holes are bored. There are cases where the buttons may come so close together that it is not possible to get the test indicator in between them. This has been provided for in the buttons made by Brown and Sharp, as shown in

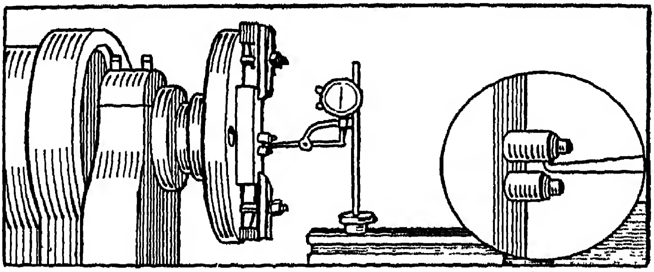


FIG. 14. LOCATING JIG IN FACE PLATE OF LATHE

Figs. 13 and 15, where it will be seen that one button is longer than the others. The object of this is that the longer button can be located first, as it affords a place where the indicator can make the test.

There are cases where a jig may be of such a kind that it is not possible to fix it to the face plate of a lathe. In such cases the jig may be fixed to a milling machine, as shown in Fig. 15. In this instance a test indicator of a different kind is used. The rest of the process is exactly the same as if the work were being done in a lathe. The lathe method is much the better plan and is far quicker. The exact truth of the button can be more accurately ascertained in the lathe than in the milling machine.

Spotting Drills and "Dimples." In some cases where extreme accuracy is required, spotting or cylinder drills are used to form what are sometimes known as

" dimples," Fig. 16. The object of such drills is to offer a better and more accurate bearing surface between the drill and its guide. Such drills consist of a plain cylindrical rod formed at the end only into the shape of

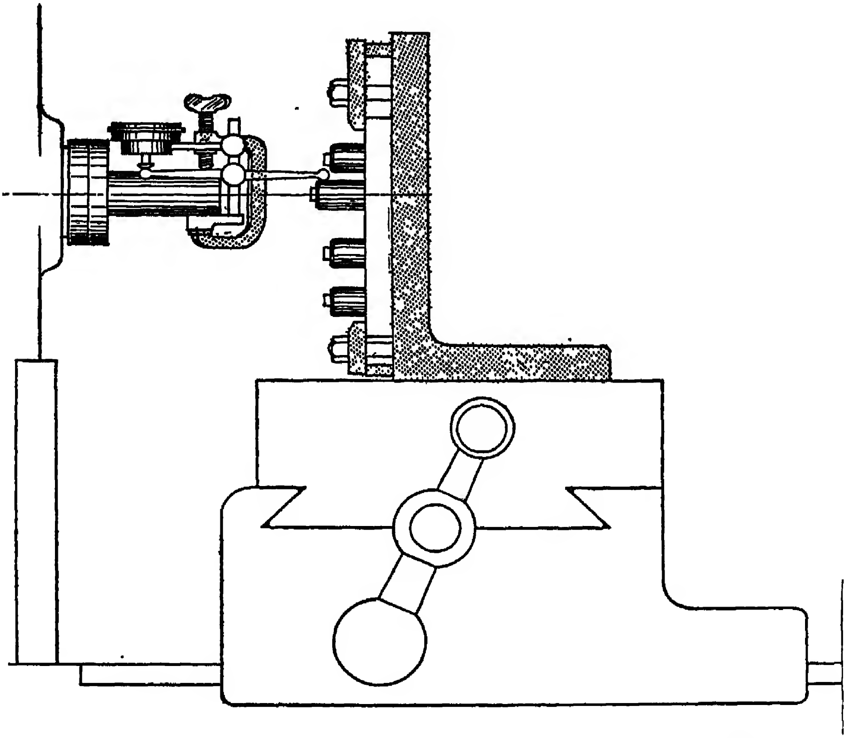


FIG. 15. BUTTONS AND TEST INDICATOR AS USED IN A MILLING MACHINE FOR LOCATING THE HOLES IN A JIG

a drill, and only so far as to enable them to form a dimple, which if just a little more than the chamfer of the cutting point, affords a perfect guide for an ordinary drill. The greater accuracy of the work produced can be accounted for by the fact that the cylindrical portion of such drills affords a more accurate means of locating the hole than the two lands of the ordinary drill.

When this class of drill is used the bush should be removed whilst the ordinary drill is at work, to prevent undue wear on the bush. In cases where the work can be laid flat on a table, the work may be removed after dimpling, and laid flat on the table for the completion of the hole without the jig.

Box Jigs. Such articles as the frames of sewing machines, typewriters, etc., are usually dealt with in drilling operations by being placed inside a box jig, in which bushes are fitted to all parts where holes have to be drilled, in the work. The box jig is usually used in connection with a multi-spindled drilling machine, each spindle carrying a different size of drill. About six spindles are usually found sufficient, as designers of such machines should take care that not more than six different sized drills are necessary.

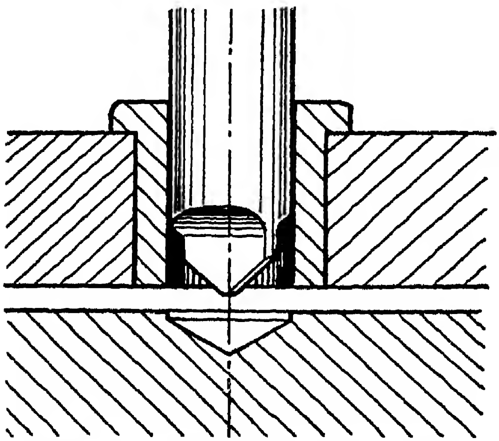


FIG. 16. CYLINDER OR SPOTTING DRILL AND DIMPLE

In the use of such jigs it is usual to provide some locating points on the casting to be operated upon. These often take the form of small projections which can be made to bear against projecting parts of the box jig, clamps, or set-screws holding the work in place without distortion. In some cases the casting has some operation done to it, such as planing or milling, before it is placed in the box jig. When this is done, the part previously operated on is usually employed for the purpose of locating the work in the box jig.

In cases where the articles are slender, and consequently difficult to hold securely without distortion, the plan is sometimes adopted of drilling the larger holes first, and inserting pins into them whilst a further hole is drilled, when a further pin can be inserted, thus preventing any movement of the work whilst it is being drilled, as unless a very secure hold can be relied upon drills are likely to cause movement of the work and to destroy accuracy.

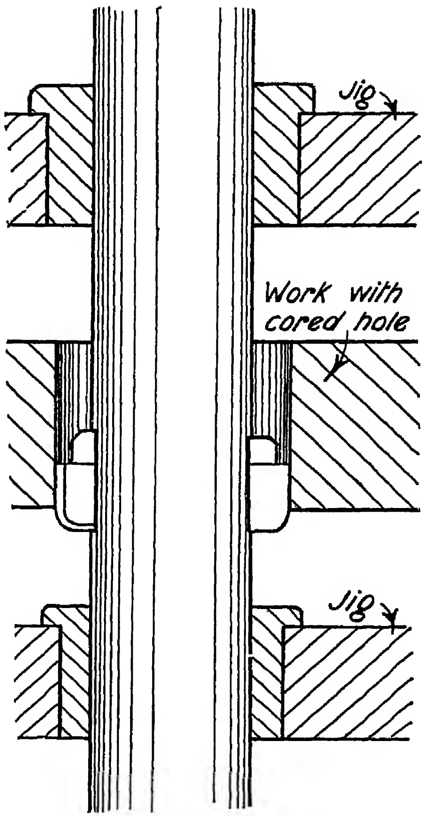


FIG. 17. ARRANGEMENT OF JIG FOR BORING CORED HOLES IN A DRILLING MACHINE

BORING HOLES THAT HAVE BEEN CORED

To attempt to make a jig that will bore holes to accurate positions that have been cored is not often done, as unless very special means are used a drill will follow the cored hole, no matter how well guided by a jig. Ordinary drills which have a cutting point ground to an angle will follow any hole that may be present in the work, perhaps not when they first enter, but as they go deeper down, the drill itself will bend sufficiently to destroy the truth necessary for even the roughest class of work. Experienced designers who recognize this fact will be seldom found to design a part where holes

that have been cored are to be jig drilled, so it is usual in designing to abandon the idea of coring holes that have to be accurately positioned. There are cases, however, where the bulk of the metal to be removed in very large holes is so great that coring is advisable. In such cases it is usual to make the drilling jig so that it embraces both sides of the work, affording a guide above the work and a guide below it for a pilot. In

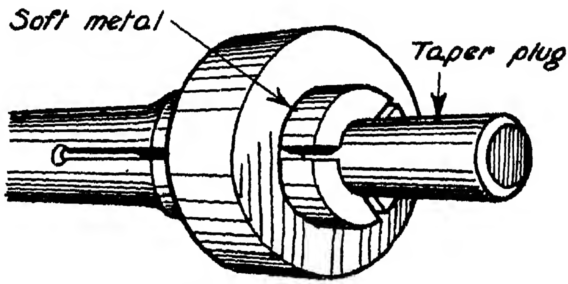


FIG. 18. AN IMPROVISED LAP FOR GAUGE MAKING

such cases it is usual to employ a flat cutter as shown in Fig. 17.

There are cases where tool-makers are called upon to do impossibilities, owing to the want of shop knowledge by the designers in the drawing office, so should a tool-maker be asked to make a jig for accurately determining holes that have been cored, it is best to point out the difficulty before starting on the job, otherwise the tool-maker may be blamed if the work produced by the jig is not accurate.

USEFUL MAKESHIFTS IN GAUGE MAKING

In shops that are not equipped for a high class of work, it will often be found that no grinding machines are included in the plant, therefore it is useful in such cases to know how accurate gauges can be made without grinding machines.

Ring Gauges. These can be made of either mild steel well case-hardened or of carbon steel. They should be bored to a few thousandths less than the required diameter, then hardened, and placed in boiling water to relieve them of strains. After this they can be ground or lapped out to the required diameter by the following means.

A piece of copper, soft brass, or aluminium should be held in a chuck and bored up for some distance, then a tapering reamer should be introduced so that a taper pin can be tapped in to expand it when it has been slit, as shown in Fig. 18. The corners should be rounded off with a file so that the abrasive shall not be scraped off by sharp edges. A suitable abrasive should then be sprinkled in the lap and the ring gauge placed on it, and the taper pin lightly tapped in so as to expand the lap. Suds made from cutting compound or oil can be used during the lapping.

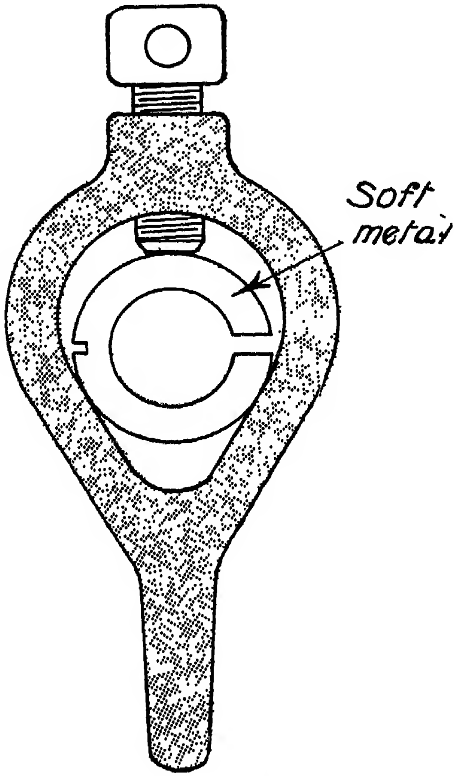


FIG. 19. SPLIT RING PLACED IN CARRIER FOR LAPPING PURPOSES

Plug Gauges. These can be made by turning either carbon steel or case-hardened mild steel to a few thousandths over the diameter required, then making a

ring of copper, soft brass, or aluminium of such a size that it will just pass over the plug. This should be split as shown in Fig. 19, and placed within a carrier, and by gradually compressing it a lapping action will remove all irregularities and make a fairly accurate plug gauge.

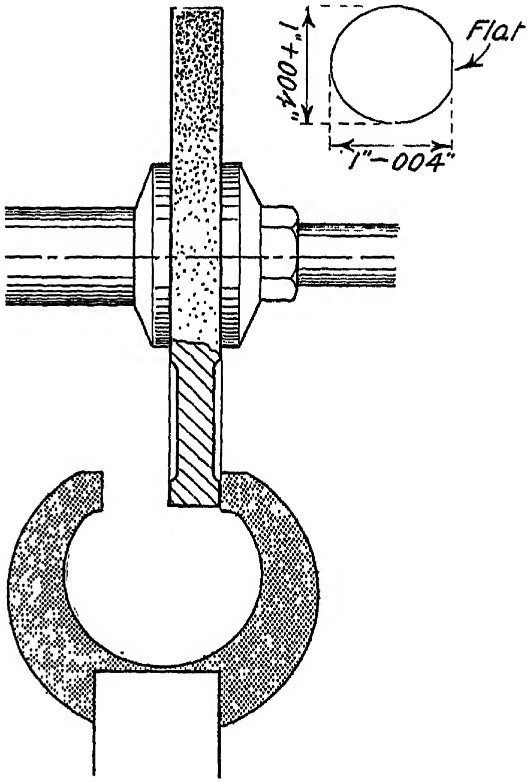


FIG. 20. GRINDING THE JAWS OF A SNAP GAUGE

Snap and Limit Gauges. Where no grinding machines are installed, these can be made with tolerable accuracy in the following manner. The gauge having been forged or cut out of plate carbon steel, or mild steel case-hardened, should be placed in boiling water to relieve strains.

An emery wheel mounted on a spindle in a lathe should have its sides turned away with a trimmer until merely a thin ridge is left on both sides, as shown in Fig. 20. The gauge should be held in the slide rest and brought in contact with the wheel. The slide rest should be wound in and out so that the wheel passes over the part being ground rapidly, taking only very little off at a time. The gauge should be kept cool during the grinding. Several gauges can be ground at the same time if placed one on the top of the other.

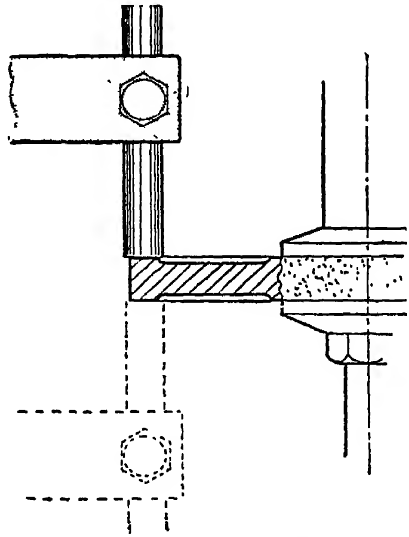


FIG. 21. GRINDING ENDS OF SPINDLE GAUGE

Gauges for making these snap gauges can be easily made in the form of cheese-shaped discs. In the case of limit gauges of the "go and not go" type, the two diameters can be made by forming the cheese to the size of the larger diameter, then filing a flat to give the diameter of the smaller dimension. By these simple means gauges can be made that are quite good enough for all but the most accurate work.

MAKING TEMPLETS

The making of accurate templets is sometimes a tedious job, but there are many ways in which the work may be made easier. In templets which are marked off with scribed lines. to which the contour has to be filed, it is best first to file or grind the surfaces on both sides perfectly flat and free from all scale. A

solution of sulphate of copper (bluestone) with a few drops of sulphuric acid added, can be used to give a thin coating of copper to the surface to be scribed. A lump of bluestone rubbed over the surface with a few drops of water, will have the same effect. This method makes the scribed lines much plainer and more easy to follow. One or all the edges should be perfectly square,

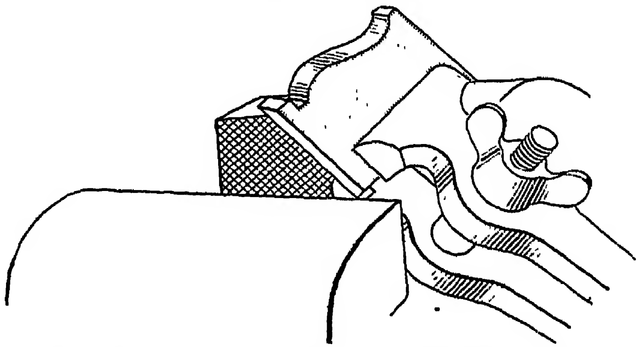


FIG. 22. TEMPLET GRIPPED IN HAND VICE

so that a set-square or bevel can be used for lines that are to be made with the scriber. Having marked out all lines, a great deal of time can be saved by holding the templet in a strong hand vice as shown in Fig. 22, set at an angle of about 30 degrees with the larger vice jaws. The unwanted metal can then be filed away until the lines are approached. The file can then be tilted until the lines are more nearly approached, and eventually the angle of the hand vice in the larger vice can be reduced until the work can eventually be held upright in the large vice and the templet finished off with an edge that is at right angles with the face.

With this method there is less likelihood of filing past the scribed lines than when the templet is held upright throughout the filing operation.

Making a Templet to Fit Another, or to Fit a Piece of Work. Where a templet has to be made to fit another

templet, it is usual to lie the existing plate over the piece of steel that is to form the new plate, and to scribe the contour.

The method just described can then be followed, but the use of the contrivance known as the "Dixie-box," described elsewhere, will be found very useful. Should this not be available a piece of plate glass can be used

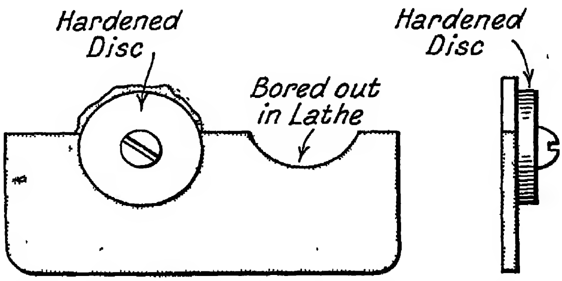


FIG. 23. TEMPLETS WITH CIRCULAR RECESSES

to hold the two pieces in the same plane whilst examining them as they are held up to the light.

Where templets have recesses which form part of circles, as shown in Fig. 23, it is quickest to chuck them on the face plate of a lathe, setting the centre point by the indicator shown on page 1045. The recess can be bored away to fit a disc previously made for the purpose.

Where a projection has to be formed which forms part of a circle, a disc can be made of steel which can be either hardened or case-hardened, and clamped against the templet so as to form a guide for the filing. Straight parts can be filed with ease if a piece of case-hardened steel is clamped against the work. Hollows or projections which form parts of ovals can be easily formed by cutting from a rod a slice at an angle, and clamping it against the work, as shown in Fig. 24, whilst filing, the oval disc can be reversed so that the form can be entirely produced by filing to the hardened guide.

The oval can be easily determined by procuring a rod the diameter of which is that of the minor axis of the oval required. The rod can then be cut off at such

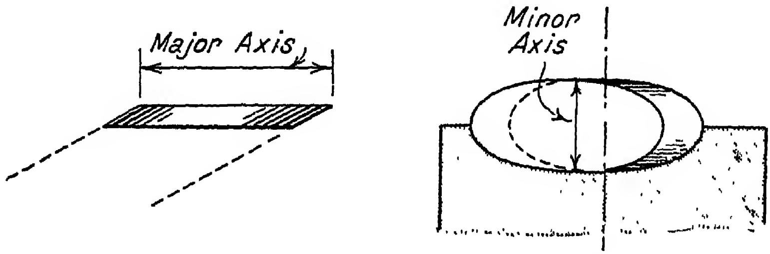


FIG. 24. OVAL TEMPLETS MADE FROM BAR

an angle that the face left is equal to the desired major axis.

When making a templet to fit a piece of turned work, such as that shown in Fig. 25, the easiest and quickest way is to cut the article in half, that is to say, to leave

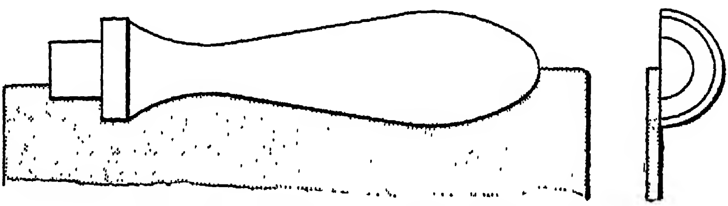


FIG. 25. MAKING TEMPLET FROM TURNED SPECIMEN

a complete half, as shown in Fig. 25, this can be used to scribe a templet from, and can afterwards be used in the "Dixie-box" or the piece of plate glass.

In cases where acute angles have to be filed out, such as that shown in Fig. 26, a square file can be ground away to fit a bevel, a piece of hardened steel can then be clamped to the templet being made, and the ground part of the file laid against it as a guide. By this means an acute "V" can be formed with great accuracy and ease.

HARDENING AND TEMPERING

Nothing is more annoying to a tool-maker, who has spent hours on making some article, than to see it fail in use; a die may crack or it may crumble at its edges when in use; a tap may break as soon as strain is brought to bear on it. Such happenings do not improve one's chance of promotion. The writer has known tool-makers who were reliable in every way, excepting in

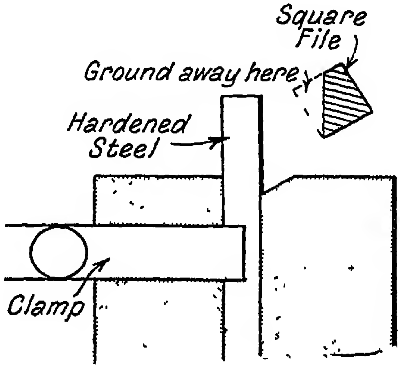


FIG. 26. TEMPLET WITH ACUTE ANGLES

hardening. In some cases it may be due to an obstinate disregard for the precaution of shading the object from a bright light whilst heating it, or it may be due to some form of colour blindness which prevented them from judging the colour. In hardening tool steels, there is no harm done if one under-estimates the heat at which it will harden, so it is best always to be on the safe side; try it at a low heat first, if it does not harden, try again at a very slightly greater heat.

With regard to quenching, there are two views on the subject; some prefer to quench in oil, whilst others prefer water. To quench an article of any size in oil, it is necessary to raise the heat far above that at which it will harden in water. It is true that oil is less liable to

set up cracks, but other troubles may arise through the higher temperature to which the article has to be raised. For general work the writer prefers water in which salt has been dissolved, as used by file-makers. In some cases the water may be slightly warmed for some brands of steels, but where this is necessary, it will usually be found referred to in the instructions given by the makers of the steel. Great care should be taken that no vessel that contains traces of soap should be used, such as a pail that has been used for washing hands, as soap is fatal to the sudden chilling necessary for the hardening of steel. Strong soapy water can be used with safety to cool out parts that are not required to be hardened. Should a number of articles be required to be hardened one after the other, the water in which they are dipped will begin to rise in temperature, so a wise plan is to use a metal vessel and to stand it in a larger vessel in which a stream of cold water is allowed to flow. It is quite wrong to imagine that steel can be heated to a high temperature, then by allowing it to cool down to a reasonable low temperature it can be quenched with safety.

All tools should be quenched at a rising temperature, not at a falling one. One of the safest fluids in which to quench articles that are likely to crack owing to their having very thin and thick parts, is commercial sulphuric acid, the writer having seen results produced with this used for quenching that could not be equalled by any other means. It is, however, a very dangerous fluid to have about a workshop. It should be kept in a lead-lined iron vessel, which should be strapped to a wall to prevent it from being knocked over. On no account should an earthenware vessel be used, as if broken the acid will escape. A lid with a padlock should be provided, and only a responsible man should keep the key. Above all, those who dip articles in it should

be *made* to wear goggles, as should any article slip from his tongs and cause a splash acid may enter his eyes, the loss of sight being the sure result. The use of sulphuric acid is not general practice. If oil is used, whale oil is probably the best for all round use. Fish oil or even cotton seed oil can be used. As no definite rule can be given which applies equally well to all grades of steels, the above directions must be taken as general rules applying to most brands of carbon steels, but one of the best methods of determining the treatment most suitable is to procure all tool steels from some firm of repute, such as Edgar Allen & Co., Ltd., or Thomas Firth & Sons, Ltd., of Sheffield, and to follow the instructions issued by them relating to the hardening of the special brands used for the various purposes of tool-making.

The following piece of information must not be regarded as standard practice, as it is not generally known, the writer having struck it by a pure accident. In the hardening of very small milling cutters, such as those used for clockwork gears for instrument work, warping is a serious matter, as it will have the effect of making the tooth gap made by the cutter too wide, and the teeth too thin. The writer found that by filling the lid of a tin box with little more oil than will cover the cutter and quenching the cutter in this, that the edges of the cutting teeth became hardened, the oil by then becoming so hot that it had no hardening effect on the body of the cutter, which was left soft and did not warp. By filling a tube with just sufficient water or oil to harden the outer surface of a tap, the centre core can be left in a semi-hardened condition.

To emphasize the points mentioned, we repeat never overheat carbon steels, either for working or hardening.

There is no secret or magic in carrying out any of the following processes in connection with the steels used

for tool-making: annealing, working, hardening, and tempering. Some mechanics will profess to have acquired special knacks, or to have inspired knowledge which enables them to do things which others cannot do; this, however, is all nonsense; there is only one rule, and that *must* be observed, it is never to heat tool steels beyond a cherry red or 780° – 800° C. (1436° – 1472° F.).

In large shops the modern plan is to use special furnaces for the above operations, but in a great number of shops the tool-maker has to do the best he can with an ordinary forge or a gas blowpipe, and if he knows what to do he can produce very good results. The annealing of tool steels is not so important now as it was in the past, as most of the makers of such steels will supply it in a far better annealed state than is possible to produce with any ordinary equipment. All tool steels should be ordered "annealed," and the writer can see no need for bars of steel being delivered in an unannealed state, as it only means waste of time and money. Care should be taken when using annealed steels to allow at least $\frac{1}{32}$ in. to be machined off the part, as the outer skin of well-annealed steels is often found to have been robbed of much of its carbon content.

If annealing has to be done, however, it should be understood that there is no secret or magic about it, it is merely a process of heating and allowing the steel to cool very gradually, the more gradual the cooling, the softer the steel.

If a forge is used, it is best to do any annealing at night, by making up a good fire and placing the work in the centre, taking care not to blow the fire up after placing the work in it. By this means the work will never be raised above a safe heat. When the work is hot, the fire should then be closed over it and left until the morning. Where this is not possible, as a forge

may be wanted for other purposes, several shovelfuls of hot fire should be placed in an iron box with a layer of ash under it. The work should then be made just red hot, placed on the fire in the box, covered with more fire from the forge, and also with more ash. This will make a fire that will take some hours to die down.

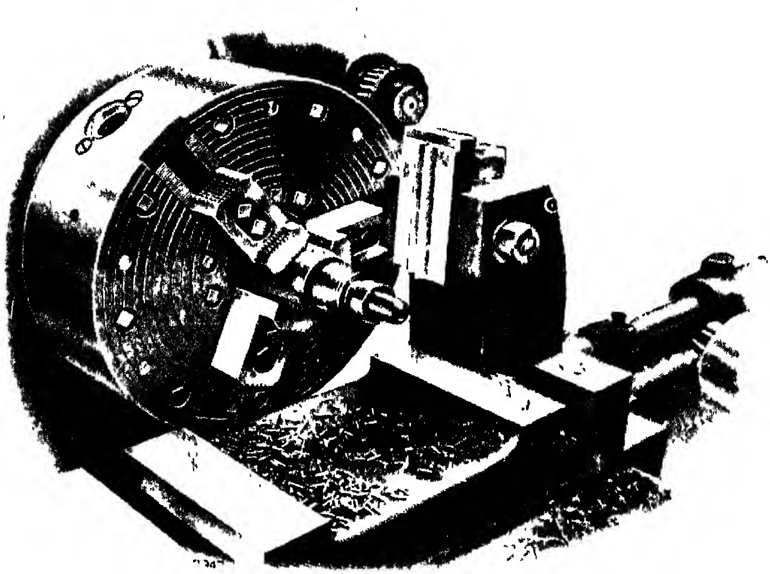
When forging tool steels, the only things to guard against are making it too hot and forging it when too cold ; there is nothing else in it. When heating tool steels for forging, annealing, or hardening, in a forge or with a blowpipe, it is essential that the place where the heating is carried out should be very dark, as it is impossible to judge the heat if a bright light is present, and entirely out of the question in bright sunlight. If there are windows near the forge, shields should be placed against the window to keep the daylight away. Some mechanics will ignore this precaution, or dispute it. The result of this the writer has seen, viz., that a fairly large proportion of the work they produce fails when put into operation. The usual thing then is to blame the steel.

Overheating is just as injurious when annealing as when hardening, although many do not realize this ; steel once overheated is ruined for tool-making for ever. All the evils such as short life, warping, developing cracks, and breaking under strain can be attributed to overheating at some period.

THE MAKING AND USE OF FORM TOOLS

The form tool is one that imparts a special form to the work, an example of which is shown in Fig. 27, where a piece of work is being produced which has in one part a groove, a projecting ridge on the tool forming the same. Form tools are made in two kinds, the straight, as shown in Fig. 27, and the disc tool, as shown in Fig. 29.

For heavy work the straight kind is mostly used as it can be held more firmly in the rest, whilst the disc tool is more difficult to support rigidly, as its use often necessitates a considerable amount of overhang, which causes chattering. In turret lathes, a form tool is usually placed in the back rest, as tools held in that way



(*Alfred Herbert & Co.*)

FIG. 27. A FORM TOOL AND ITS HOLDER

are more free from vibration and consequent chattering. For forming such simple articles as that shown in Fig. 28 they are more suitable than the use of box tools, providing that the article to be produced is not of any great length. When long work is to be produced, a form tool is likely to cause the work to ride up on the tool as the cutting edge is a long one.

To make a form tool to produce any particular contour, would appear to be a simple job, but in reality it

is not so. Taking the case of Fig. 30, the difference in the diameters is $\frac{1}{4}$ in. on the contour, so it would appear that if a tool were made as shown in Fig. 31 where one step is $\frac{1}{4}$ in. lower than the other, the correct contour of work would be produced. This, however, is not the case, as the cutting end of a tool has to be cut at some angle which is less than 90 degrees, otherwise there would be no front clearance, or the cutting surface, which we will for clearness refer to as the "top," would have a negative rake, which is well known would not allow the chip to be cut properly. The angle of clearance, or what we will refer to as "front rake," in form

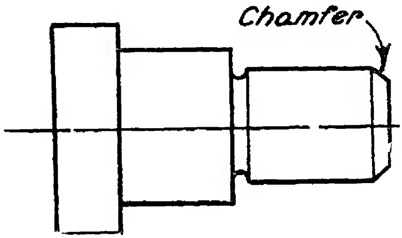


Fig. 28. A Job which can be Executed by a Straight Pattern Form Tool

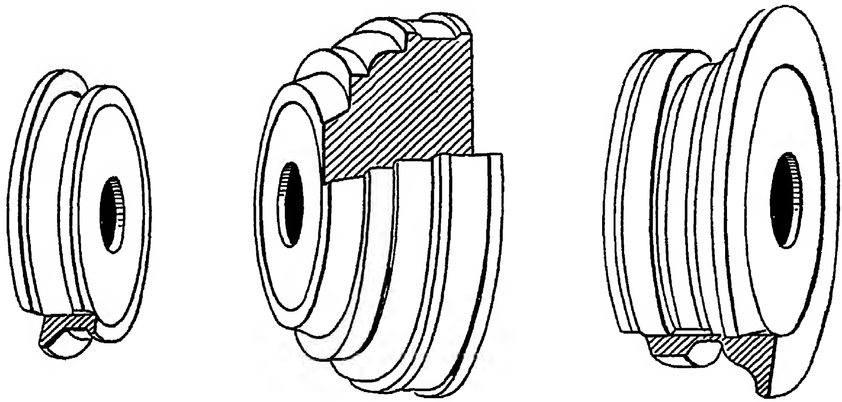


Fig. 29. Disc Type Form Tool

tools depends on the material being worked on and the nature of the contour. Brass or all yellow or soft metals require a greater angle of front rake than the harder

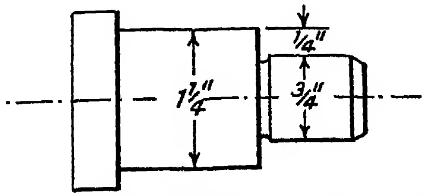


FIG. 30. JOB WITH DEEP SHOULDER

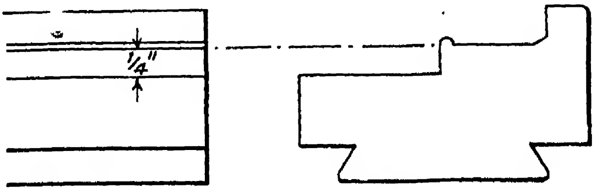


FIG. 31. FORM TOOL FOR ABOVE JOB

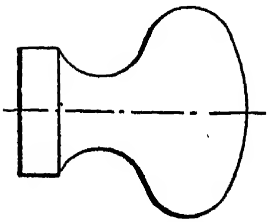


FIG. 32. TOOL WITH CONTOURS HAVING NO ACUTE ANGLES

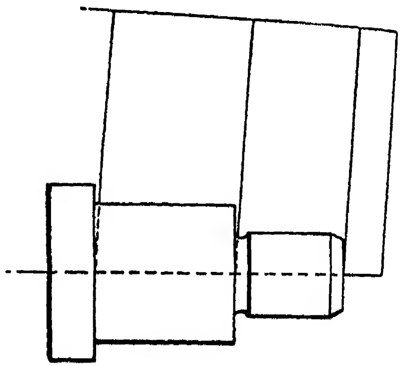


FIG. 34. SHOWING HOW A TOOL MAY BE INCLINED TO ONE SIDE TO PREVENT BINDING

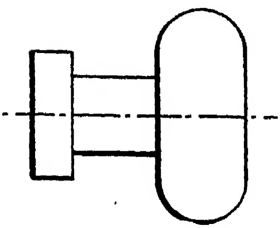


FIG. 33. TOOL WITH ACUTE ANGLE CONTOURS

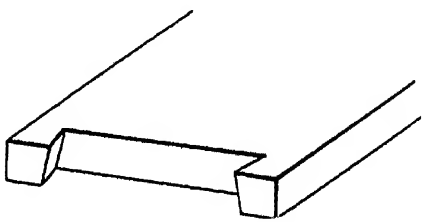


FIG. 35. SPECIAL TYPE OF FORM TOOL

metals such as cast iron or steel. Contours such as that shown in Fig. 32, where the curves or angles do not form acute angles with the axis of the work, may have a slight angle of front rake, as they easily clear themselves of the work, but tools of the form shown in Fig. 33, where the angles and curves are at 90 degrees with the axis, or where curves approach that angle, should have a much greater angle of front rake, otherwise there will be considerable binding and dragging of the work against the sides of the tool.

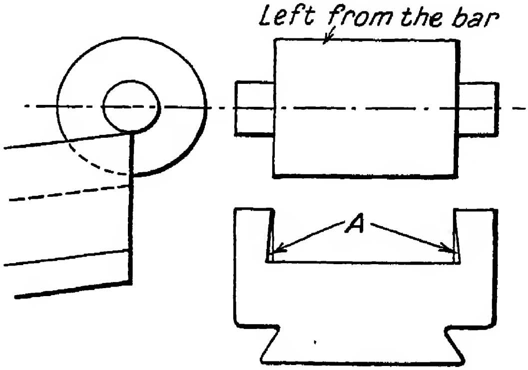
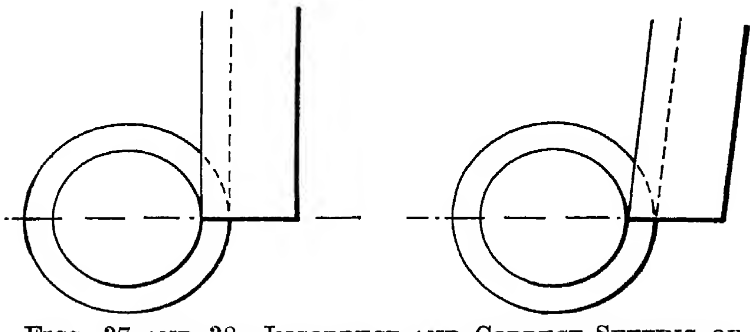


Fig. 36. Showing Relief Clearance Given Tool when the Job has Shoulders

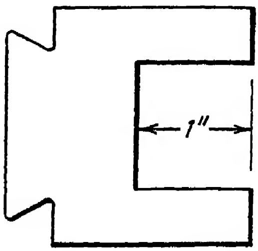


Figs. 37 and 38. Incorrect and Correct Setting of Form Tools

In a form tool in which all steps are in the same direction, as in Fig. 30, better work can always be produced if the tool is given a slight inclination to one side, as shown in Fig. 34, as it relieves the tool from all

dragging at the sides. Such an article as that shown in Fig. 36 may be produced by a form tool, but if the shoulders are of considerable depth, dragging at the sides will become troublesome after a comparatively few articles have been produced.

Some tool-makers contend that if the tool is given clearance, as shown at *A*, there will be no dragging. This, however, is not correct, as such clearance will only relieve the work from dragging at the part where the actual cutting takes place. Form tools can be made as shown in Fig. 35, which is a front view of the tool, but such tools are of little use, excepting for the production of very small numbers of articles, as so soon as they are ground on the top, or cutting face, the gap between the two cutting corners becomes wider, and the correct contour is lost.



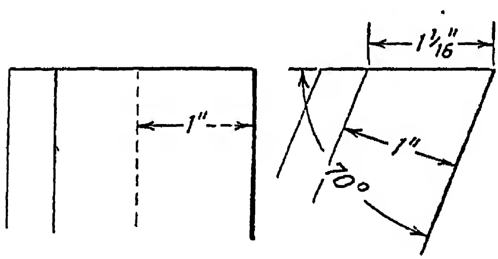


FIG. 39. SHOWING THE EFFECT OF FRONT RAKE

Where articles such as that shown in Fig. 30, with considerable differences in diameter and consequently deep shoulders, have to be produced, it is best to form one of the reduced parts by a box tool, and to form the other by means of a form tool. In the use of form tools that are fed towards the work, it must be borne in mind that the top of the cutting face must always be radial and on a plane with the axis of the work. Fig. 37 shows tools that are wrongly set, whilst Fig. 38 shows tools as they must be set to work properly and to produce a formed article.

Realizing that the plane of the top face must be radial and on a plane with the axis, and that front rake is necessary, it will be apparent to any thinking person that if a straight form tool is made so that the article to be produced will lie on it without showing any gaps, that when the top of the tool is ground away at an angle of even 10 degrees to give the necessary front rake, the work produced by such a tool will not be exactly like the sample that would lie on the tool without showing any gaps. To make this point perfectly clear, we will take an exaggerated case of supposing that a form tool were made with a step 1 in. deep, then ground to an angle of 70 degrees for front rake. The work produced by such a tool would be $1\frac{1}{16}$ in. deep in the step instead of the required 1 in., as shown in Fig. 39. The same thing applies to disc tools, which will not work if gashed in a radial line, as shown in the illustration, Fig. 40, but must be gashed at a tangent, as shown in Fig. 40A. Fig. 41 is an exaggerated case of a disc tool, the step of which is 1 in. from one diameter to another, if measured in a radial line, but if gashed on a line as shown, the difference between the diameters it would produce would be $1\frac{1}{16}$ in. instead of the required 1 in. This point needs stressing, as it is one of the pitfalls into which an inexperienced tool-maker may easily fall.

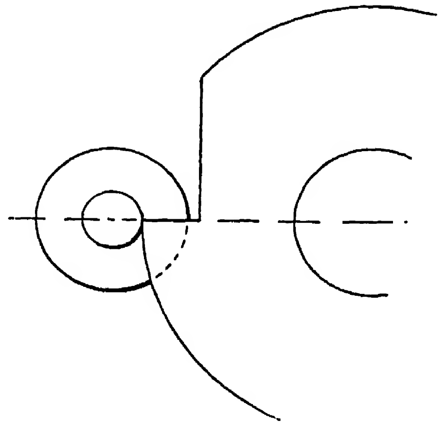


FIG. 40. DISC TOOL GASHED ON A RADIAL LINE

Having realized this fact, the next thing is to see how

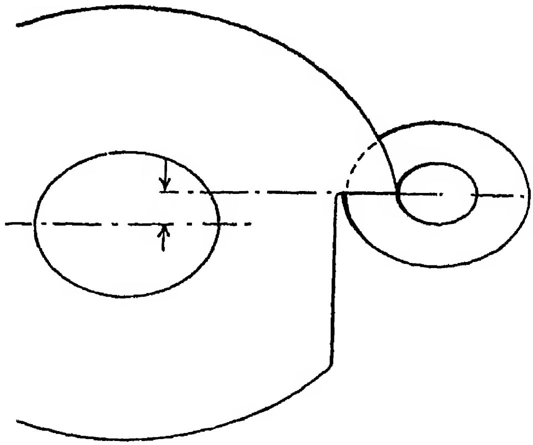


FIG. 40A. DISC TOOL CORRECTLY GASHED

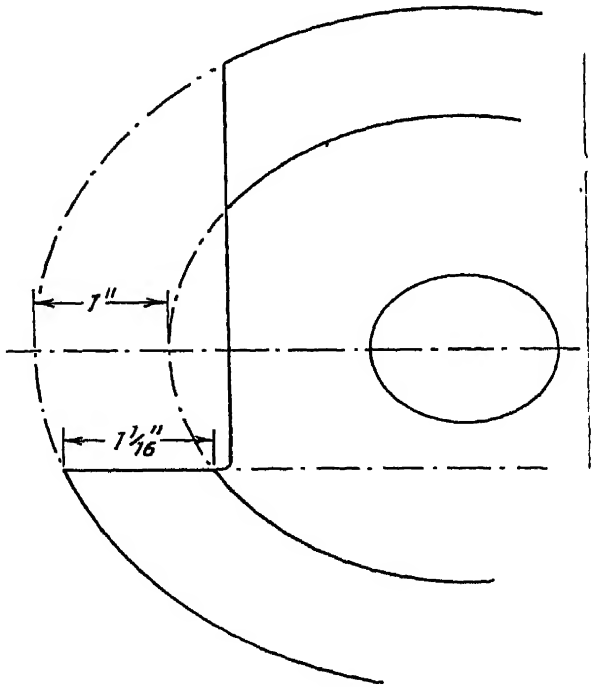


FIG. 41. DISC TOOL WRONGLY GASHED

such tools can be made with ease and certainty and without complicated calculations.

The fact that many do not realize this point may be accounted for by the fact that many small articles which are made by means of form tools, having only slight differences between the diameters produced, so slight that the difference in the form of the tool and in the contour of the work may be hardly perceptible, as the greater the differences in diameters the more apparent the discrepancy; this is the reason for the above exaggerated instances being chosen.

There are several methods of making such tools, all of which it is proposed to show, so that a tool-maker can chose the one he thinks most suited to the particular job he has in hand.

In complicated forms it is best to turn an article to the exact dimensions, curves, and angles required. This model can then have half its bulk removed in a central line. From this a templet for checking the contour can easily be made by following the directions given on page 1052 in the section dealing with templets. To make a straight form tool from this half-section it is necessary to determine the angle at which it will be ground to form its top, or cutting face. We will suppose, for instance, that this angle is decided to be 75 degrees. When this is settled, the angle must always remain constant, otherwise the contour of the work will vary. To make a straight form tool from this half section, two supporting pieces, as shown in Fig. 42, should be made, the angle of which should be 75 degrees; the half-section having been fixed to these, the tool can then be produced by means of a shaping machine. The formation of square shoulders is comparatively simple, and curves and hollows represent a more difficult matter, but these can be made easier by using spring gauge tools. A certain amount of finishing by filing can be done, but

it is best to avoid this as far as possible. The half-section kept at an angle should be used all through the operation.

In the making of disc tools, the same plan can be adopted by turning the disc to approximately the right form, then mounting it on a mandrel of a known diameter, and fixing to the half-section two arms which

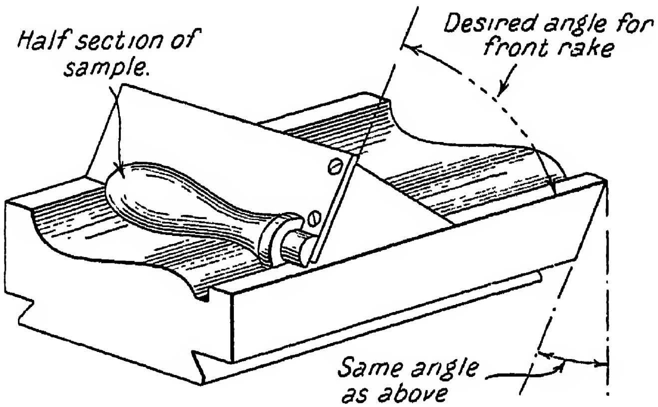


FIG. 42. DETERMINING THE SHAPE OF A FORM TOOL FOR A JOB HAVING A COMPLICATED SHAPE

can lie on the mandrel in such a manner that the templet will lie at the tangent at which it is intended to form the gash, as in Fig. 43. By the use of hand tools the disc can be easily turned to fit the templet with accuracy. No exact diameter of the disc tool need be preserved, so the turning to fit the templet is not a difficult matter. In some cases such tools are ground after turning to prevent errors through warping; in tools with curves in their contour, this is a very difficult matter, entailing the turning of abrasive wheels to the required curves, which in most cases is quite an unnecessary operation, as with well-selected steel for the purpose, warping can be reduced to a minimum. When once the tangent at which the gash is to be formed is

settled, this should be kept constant throughout the life of the tool, as any deviation will result in a departure from the original contour.

Another method by which both straight and disc tools can be made is to turn a sample article to exactly

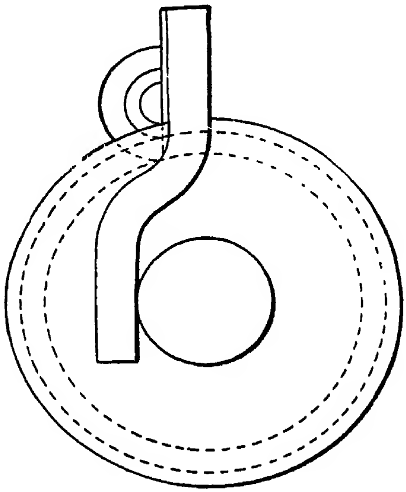


FIG. 43. MAKING A DISC TOOL

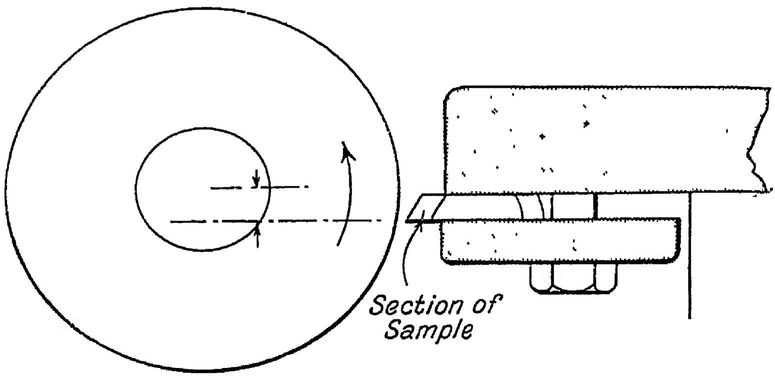


FIG. 44. ANOTHER METHOD OF MAKING DISC AND FORM TOOLS

the dimensions and form required from carbon steel, then to make a cut right through the centre, leaving a complete half. This half can then have part cut away until it is of a form that can be clamped, as shown in Fig. 44. By filing away to give the necessary clearance, just leaving the extreme edge and hardening it to act as a gauge tool, the sample can be used as a finishing

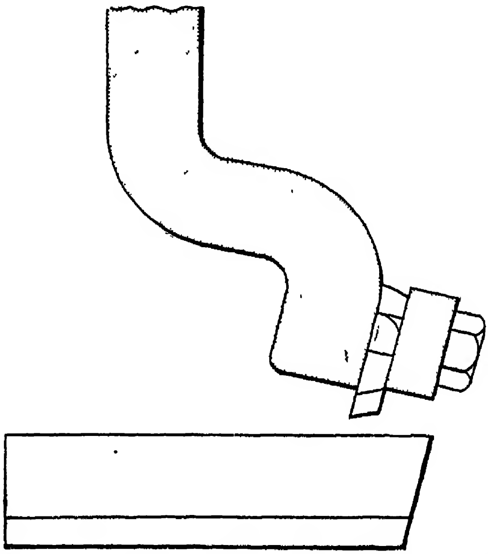


FIG. 45. USING A TOOL IN A SHAPER FOR PRODUCING A STRAIGHT FORM TOOL

gauge tool to produce a disc tool. It should be held in a holder, and set just so far below the centre of the lathe as the gash is to be from the centre.

The writer has found this method to be the simplest and always to ensure the correct contour of the articles eventually produced. This type of tool can be used in a shaper for producing straight form tools as shown in Fig. 45. In disc tools, it is best to form the gash by grinding after hardening, otherwise warping is sure to take place. It is necessary, if either of these methods

are employed, to be sure that the top of the straight tool and the angle at which the sample piece is held, should agree, also that the tangent at which the sample or the gauge tool is held in the forming of a disc tool should be the same tangent as that of the gash.

QUICK JIG-MAKING

There are cases where a jig may be wanted for a short run of articles which may never be required again, and where exact dimensions are not of the greatest importance, so long as all the articles produced are alike. In such cases it is often possible to drill one of the articles, and to make the jig from this.

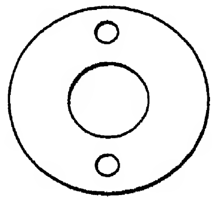


FIG. 46. SMALL NUT FOR WHICH A JIG CAN BE READILY MADE

This plan is sometimes a wise measure when dealing with malleable castings, the shrinkage of which is not easy to calculate. Levers with bosses at the ends may shrink more or less than anticipated. In such a case it is sometimes wise to wait until a first delivery from the malleable foundry is made, and to make the jig to suit the casting. There are also times when a jig may be wanted for a rush job, so it is as well to know how such cases can be met.

In small articles such as that shown in Fig. 46, which is a nut which requires holes for a forked screwdriver, the recess for it to register by can be bored out, then one of the articles can be drilled, and if found correct, can be used to drill the holes in the jig. Should the article used in this way not come out correct, it is often quicker to try again and again until one comes out right, than to mark off and drill the actual jig. In very small work the bushes can be left out, the jig itself being made of hardened steel.

Where such a jig is likely to have a lot of work and be in use for a long time, it is wise to make a master jig, which can be used to make new ones as others wear out.

MAKING IRREGULAR HOLES

In the making of irregular holes it is sometimes necessary to drill a number of holes in close proximity

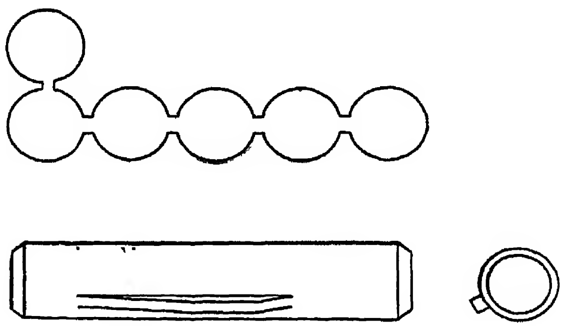


FIG. 47. EASILY MADE TOOL FOR CUTTING HOLES INTO ONE ANOTHER

to each other and to break them one into the other. To do this with a chisel is no easy matter, but if the simple tool shown in Fig. 47 is made, such holes can be cut into each other with ease. This is a piece of carbon steel with a groove milled along one side, into which is inserted a blade of carbon steel, just projecting sufficiently to break away the metal separating the holes. The longer the slope of the blade the less power it takes to drive the tool through the holes.

The tool can be used in a press, or if this is not available, it can be driven through with a hammer. In small holes it is best to make the blade solid with its body. All parts must of course be hardened and tempered to a low temper.

TOOLS FOR BORING TAPER HOLES

When any article is required which is to have a taper hole, it is not wise to attempt to bore a parallel hole out to a taper with the usual taper reamer. The reason for this is that, as the reamer gets fairly well into its work, the chips become of great length, such chips offering

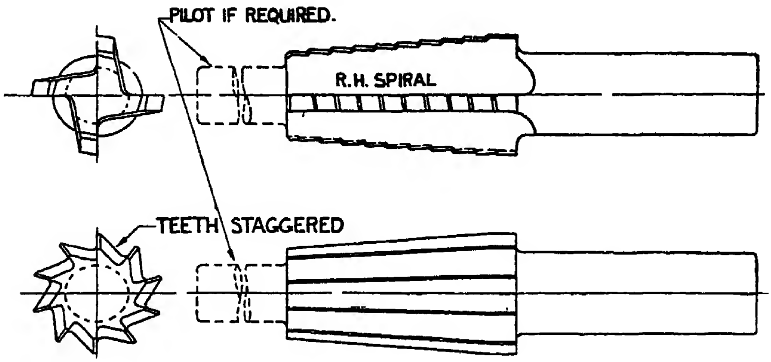


FIG. 48. ROUGHING (ABOVE) AND FINISHING (BELOW) TAPER REAMERS

great resistance to cutting. The usual plan is to use a cutter, as shown in Fig. 48, where steps are formed, each step cutting only on its end. This tool is inserted until it only leaves just a finishing cut to be taken out by the reamer with teeth along its whole length.

As the making of such reamers requires the machinery only found in the most fully equipped tool rooms, it is always best to purchase them, as those who make a speciality of the production of such articles can always give better satisfaction and produce such articles at a lower cost than is possible in the usually equipped tool room.

BORING BARS

The type of boring bar shown in Fig. 49 is not of ordinary construction, but having such outstanding

advantages over the usual type, it is given here as a distinct advance over standard practice. Usually such bars that are made to hold a single cutter, have the hole for the reception of the cutter made at right angles to the axis of the bar. This renders it impossible to measure the amount the cutter projects from the bar, unless a special gauge, which is not always available, is used.

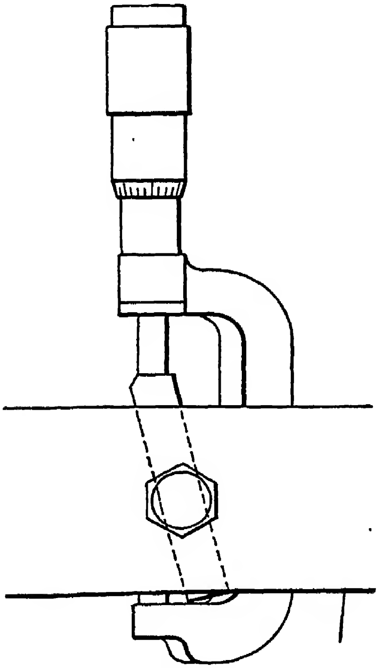


FIG. 49. BORING BAR THAT CAN BE SET BY MEANS OF A MICROMETER

The simple method of construction shown here enables a micrometer to be used for measuring the projection of the cutter from the bar, so that provided the bar is of a standard diameter, the diameter of the hole to be bored can be relied upon with certainty.

INTERNAL CHASERS

Internal chasers for use in the slide rests of turret and other lathes are usually made, but not always, by turning a shank with a projecting part which is threaded to the desired pitch and gashed away as shown. The gash should be as shown in Fig. 40, in the section dealing with disc form tools, as if made on a radial line it will be found that such chasers will not possess sufficient front rake to allow the necessary clearance.

For use in large holes the cutting part can be made separately from the shank.

SECTION XXI

TURRET AND AUTOMATIC LATHES

BY

C. M. LINLEY

SECTION XXI

TURRET AND AUTOMATIC LATHES

TURRET LATHES

THE turret lathe has undergone many changes since its first introduction. In its first form it was known as a "Capstan" lathe, with a round capstan with holes bored in to receive the stems of the various tool holders. The word capstan is still used by some to distinguish the smaller types from the larger ones. The small round capstan was followed by the Hartness, or Jones & Lamson Flat Turret, a modification of which resulted in the adoption of a hexagon turret in which the tool holders are bolted to the flats of the turret instead of their stems being held in holes, thus increasing their stability.

As the hexagon type has now become almost universal, it is proposed in this work to concentrate upon this class of turret lathe.

Turret lathes may be broadly divided into two classes, those that are intended to work from bar materials principally, and those that are designed for working mainly on forgings and castings. The former type are usually known as bar turrets, whilst the latter are known as chucking turrets. The chucking turret may be used on bar work with advantage, but although the bar machine can be used for smaller classes of forgings and castings, it is not suited for larger work, as it usually has not the wide range of speeds necessary for larger work.

One of the features which usually distinguishes the

bar machine from the chucking type is that in the former the work is gripped by collets either of the draw-in or push-out type, which are actuated by means of a cone or lever action, as shown in Fig. 1, whilst the chucking type of machine is fitted with a chuck which can be used for gripping any ordinary class of round work, and can also be used to hold bars when needed.

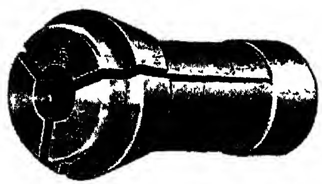


Fig. 1. Split Collet for Holding Bars

Special jaws or "fixtures" may be used when holding work that cannot be conveniently gripped by the usual jaws provided with the chuck. The chucking type is usually provided with a more elaborate slide rest arrangement, often holding four tools in front, that can be each brought into action as required, and with provision for a single tool at the far side of the work, as shown in Fig. 2.

A very small class of turret or capstan, which is especially designed for screw-making, can hardly be classed as a turret lathe, so will not be dealt with in this work.

Having now outlined the various classes of lathe that can be considered to come under the class of turret lathes, the writer wishes to give a warning to youths entering engineering works who wish to make a career for themselves.

"Robots." To learn the working of a turret lathe is a necessity for those who aspire to hold a position as tool-maker, charge hand, foreman, works superintendent or manager, but it should be borne in mind that the working of a turret lathe is not a tradesman's work; it is considered the work of a partly-skilled man. Those who never get beyond the turret operator are sometimes called "Robots," being merely human

machines. It is, therefore, not wise for the ambitious youth to dwell too long at this class of work.

The tool-setting and management of turrets is usually a highly-paid and responsible position. Therefore those who wish to hold some better position should, whilst operating a turret lathe, pay particular attention to what is being done by the tool-setter and

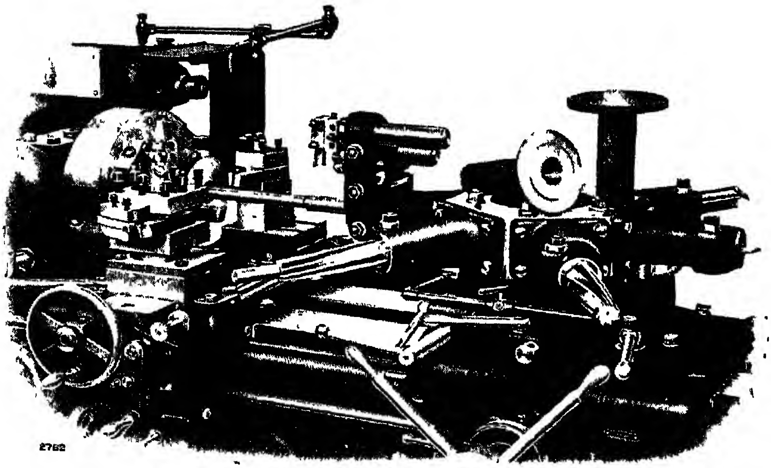


FIG. 2. CHUCKING TYPE TURRET LATHE

try to follow him in his operations, and thereby gain some really useful information that may be of valuable assistance later on.

TOOL-SETTING AND THE LAY-OUT OF TURRET WORK

The lay-out of the necessary tools and the operations to be performed on any piece of work in establishments where tool and jig draughtsmen are employed, is usually carried out in the drawing office, but in smaller shops a person in charge of the turrets may be called upon to make his own lay-out. In any case, it is as well for those in charge to know how to lay out the

work. In bar work, the operations are usually of a simple character, but certain rules must be borne in mind. The harder operations, such as the removal of a large amount of metal, should be done first, as there is always the possibility of the work being disturbed to an extent by such operations, so the more accurate work should follow the rougher.

The setting-up and lay-out for bar and chucking machines being so different, they will be dealt with separately.

THE BAR MACHINE

The bar machine, being the simpler of the two, it is proposed to deal with that first.

Feeding the Bars. In the smaller types of turret or capstan machines, the bar is fed forward after each article has been formed by means of a "wire feed," which consists of a cord passing over a pulley and with a weight at the end. As each article is parted off and the chuck opened, the wire (as the smaller types of bar materials are called) will automatically be brought forward against the stop provided in the turret to determine the length the bar should project from the chuck.

In the heavier machines this arrangement is not possible, as the weight of a heavy bar being brought to rest by a stop would cause a hammer blow. There are several means employed for feeding the bar, one of the most generally used being that shown in Fig. 3, where a sleeve is made with a ring at one end to take a yoke, whilst the other end is split up so that it can be contracted to set up sufficient friction to enable it to move the bar when it is brought forward, by means of a lever, whilst the chuck is open. The chuck is then closed, and the collar moved backwards to a position suitable for bringing it forward when the chuck opens again ; the

distance it travels is that required for each article to be produced.

When heavy bars are being operated upon it is usual to employ a "back-end chuck," which can be set so that the heavy bar will just slide through it. The object of this support is to relieve the jaws of the chuck

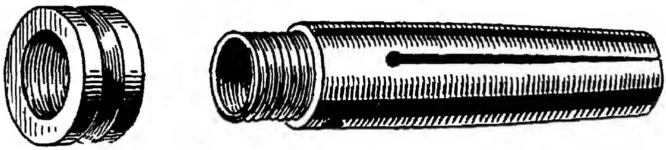


FIG. 3. EXAMPLE OF FEEDING FINGER

This grips the bar by slight friction, so it can slide on the bar while chuck is closed, but can feed the bar forward while the chuck is open

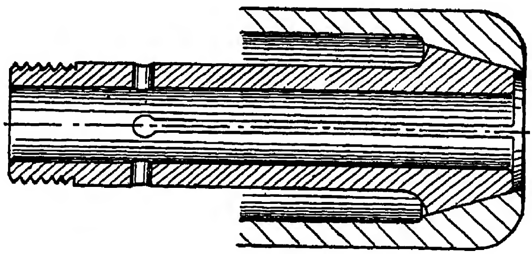


FIG. 4. POPULAR TYPE OF CHUCK FOR PRODUCTION WORK ON SMALL LATHES

from the strain of the overhanging bar. As the mandrels of machines used for heavy bars are usually of considerable length, there comes a time when the bar becomes so short that it receives no support from the back-end chuck. There are two ways in which this difficulty can be dealt with. In work that is not to be produced in very large numbers, a collar may be made to fit the bar and a sliding fit in the bore of the mandrel and fitted with a grubscrew.

The jaws of the back-end chuck can be opened to allow the collar to be placed on the bar when it gets so

short that it is not held by the back-end chuck. Another way more suitable to large output is to make a sleeve to fit the bar and to fit inside the mandrel for its whole length.

Chucks. Bars can be held in ordinary universal chucks, but for production work these are never used, as they entail the stopping of the lathe to release the bar. A common form of chuck used on the cheaper

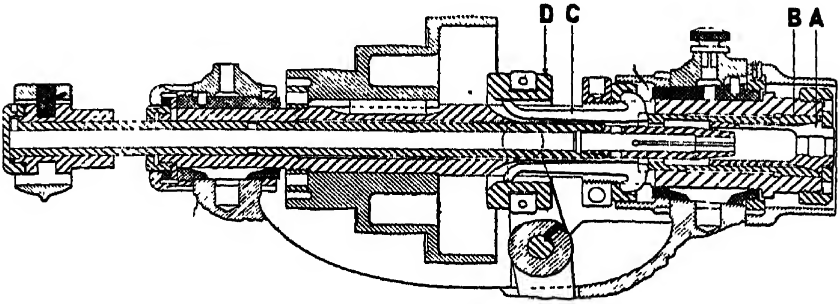


FIG. 5. A MORE EXPENSIVE FORM OF CHUCK

and smaller types is that shown in Fig. 4, where a collet is forced into a cone; the collet, being split, contracts on to the bar, and so holds it whilst it is being operated upon. This type is by no means the best form, so care must be taken to avoid trouble that may occur when there is the least difference in the diameter of the bar. A bar that is under size will allow the jaws to pass through the cone for an appreciable distance before they grip, whilst a bar that is slightly over size or with dirt clinging to it will cause the jaws to grip sooner on the bar. The result of this variation will be that the amount the bar projects from the chuck cannot be relied upon for accuracy; consequently, when this form of chuck is used, it is common practice to shave the end of the bar each time it is projected from the chuck.

A better type of chuck is that shown in Fig. 5, in which the amount the bar projects can be relied upon for accuracy. In this type the split collet *A* does not move endwise, but butts against a stop collar, a female cone *B* being slid over it to cause it to contract on to the work. There are many types, but the above description fairly covers the ground. The sliding movement of the collar *D*, Fig. 5, contracts the levers, thus forcing a

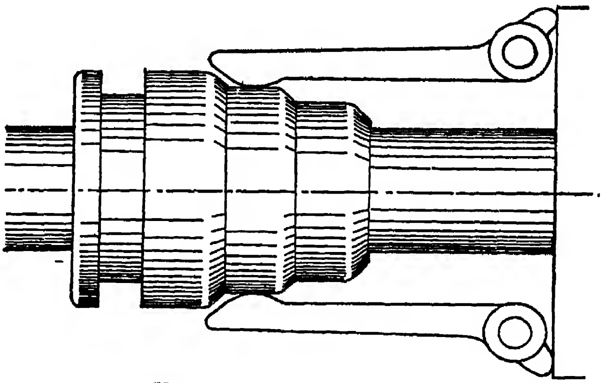


FIG. 6. STEPPED CONE

sleeve along the mandrel to cause the contraction of the chuck. It will be seen in Fig. 5 that the long ends of the levers *C* are intentionally made somewhat slender, the object of this being that they can slightly spring to permit of bars with a slight error in diameter being gripped.

In some instances what is known as a "stepped cone" is used, as shown in Fig. 6, the object being to provide a cone that will accommodate itself to bars with a slightly larger amount of error than usual, or to provide for any other inaccuracy, each step forming a cone and a parallel part for the levers to lie on, as the levers cannot be relied upon to hold the work until they have reached the parallel part which follows the conical part.

Operating Methods. As an example, a common object is shown in Fig. 7, which has a head (usually left from the bar), a body, and a screwed part. If the article is short, that is to say, not so long that it would require the support of a steady, it would under ordinary circumstances be formed by a tool made to the shape and held up-side-down in the back rest. This tool would be brought in by means of the cross slide until the stop which determines the diameter is reached, when it would be wound away from the work and the die run up, the die opening automatically when it reaches the shoulder. The cross slide, which holds a parting-off tool

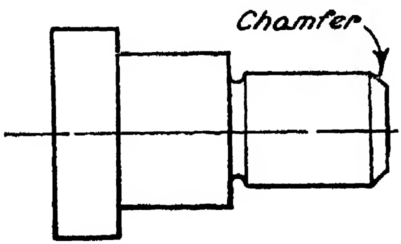


Fig. 7. Simple Object for Forming

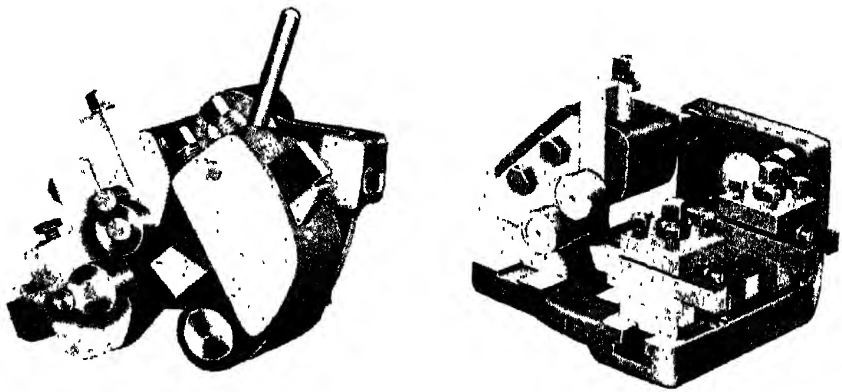


Fig. 8. Simple (left) and Double (right) Box Tools

as well as the formed tool, but opposed to it, can then be operated to part-off the article from its stock.

The turret is then brought round so that the stop, which determines the length the bar should project from the chuck, is opposite the end of the bar, the

chuck is opened and the bar brought forward, and all is ready for the production of the next article.

In cases where the body of the article shown in Fig. 7 is required to be to closer limits than in the commoner classes of work, a box tool, as shown in Fig. 8, would be used to shave the body to more accurate dimensions. Should the article be so long that a formed tool would cause chattering and produce inferior work, the bar may be first slightly tapered at its point by means of the tool shown in Fig. 9, then a large box tool used to form the body; this may be followed by a second box tool taking its bearing from the work done by the first, or two sets of tools may be arranged in the same box as in Fig. 8. The use of the formed tool is, however, quicker and always used wherever possible. Examples of formed tools are shown in Figs. 27, 29, " Jigs and Tools."

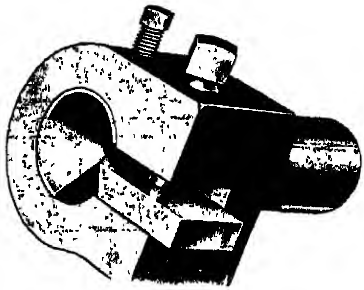


FIG. 9. CHAMFERING TOOL

Parting-off and Forming Heads. There are cases where the head of an article has to have some shape imparted to it other than the flat left by an ordinary parting tool. In screw-making it is common to have to form round heads in the operation of parting-off. Such formations are usually done in two stages. It is obvious that if the parting tool had a form on its side that would produce the round head in one operation, there would be considerable load on the tool as it nears the centre of the work, so, as the pip which holds it to the stock would be very small, the screw would break off before half the head had been formed. Fig. 10 shows the arrangement of parting tools in such cases, one having done its work and having receded whilst the

other is advancing to finish off the work. Figs. 11 and 12 show other examples of work where various shapes of head are produced in the parting-off operation. In producing an ordinary screw, such as that shown in Fig. 7, it is usual to form the necessary chamfer on the screwed part by means of two parting tools (see Fig. 11).

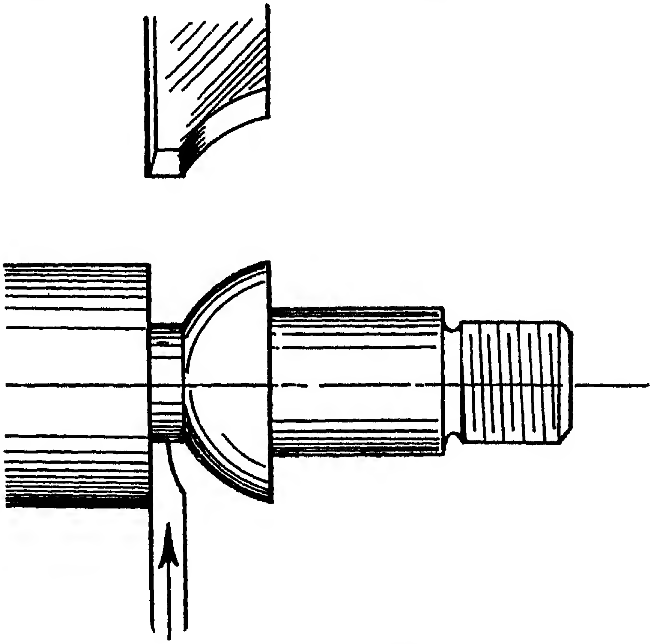
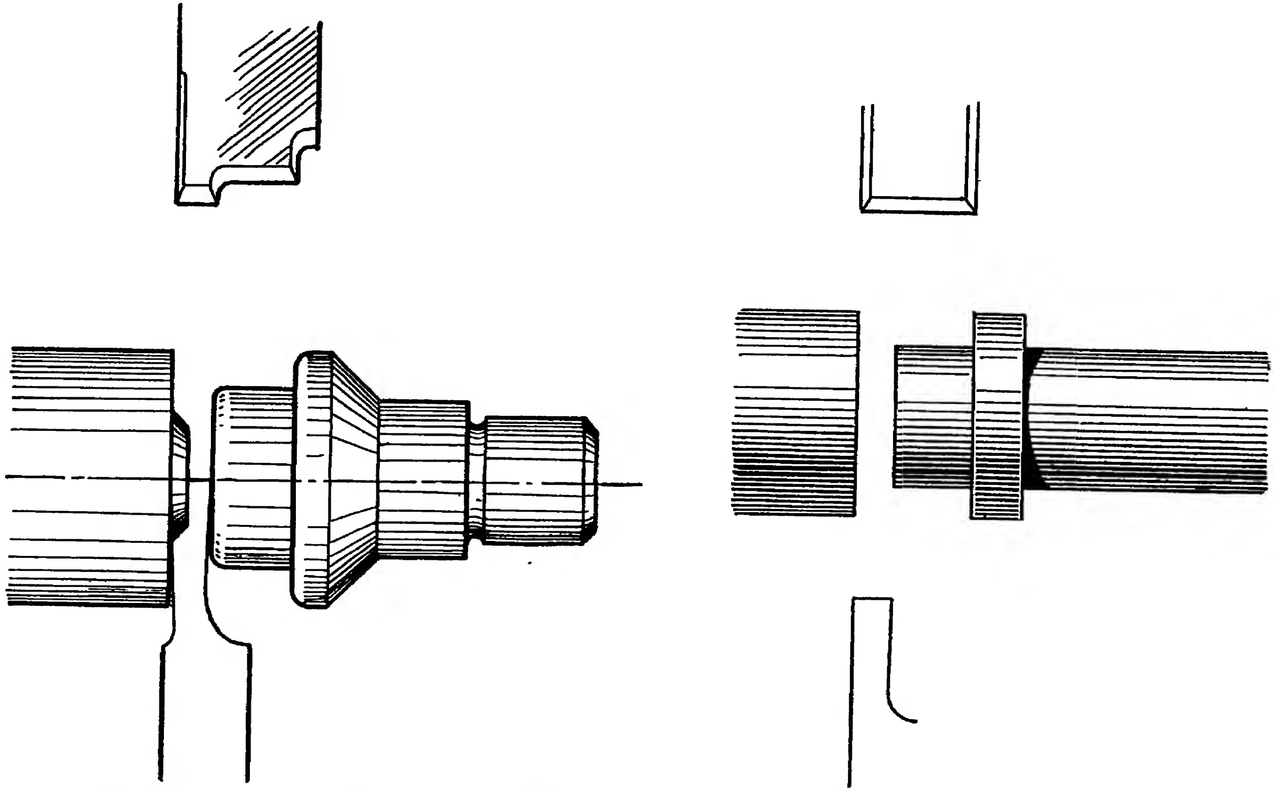


FIG. 10. USE OF PARTING TOOLS

Knurling. This operation used to be performed by pressing the knurl towards the work, but the plan could never be relied upon to produce a perfect knurl. In the first place, unless the article was of a short and stiff character, it was not able to bear the pressure necessary to produce a clean and fully developed knurl.

The modern method is to pass the work between two knurls adjusted to a pre-arranged distance apart, the distance being slightly less than the diameter of the



Figs. 11 and 12. Examples of Work when Various Shapes of Head are Produced in Parting-off

work before knurling, thereby producing a balance of pressure which does not distress the work. The knurls can be adjusted to any angle (see Fig. 13).

Screwing and Tapping. In such work as that usually done in bar machines, external threading is generally carried out by means of a self-opening die, the die once started, travels up the work until the desired point is reached, when an automatic arrangement, sometimes

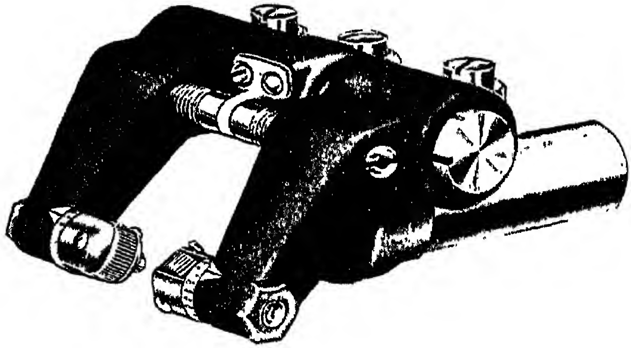


FIG. 13. KNURLING TOOL

operated by the end of the work, causes the die to fly open. In smaller work the self-opening die is not always used, so the solid, or button die takes its place. In this case the die is held in a holder which, when it reaches the point where the thread is to terminate, becomes detached and revolves with the work. The mandrel is then reversed and the die screwed off its thread; in doing so it travels back with its holder into its place in the turret. Of the self-opening type there are several really good models on the market of both English and American make. In such work as that which is carried out in the bar machines, internal threads, if there is a hole right through the piece of work, are best tapped in a second operation, using a long tap, which owing to its length will not throw up burrs at the ends of the hole.

There are, however, cases where no hole can be permitted to go right through, or where a shoulder is met with. In such cases tapping has to be carried out in the machine whilst the article is still in the chuck. Where such holes are large enough, it is best to use a collapsible tap, which acts on very much the same principle as the self-opening die, the blades which carry the thread receding to allow the tap to be withdrawn

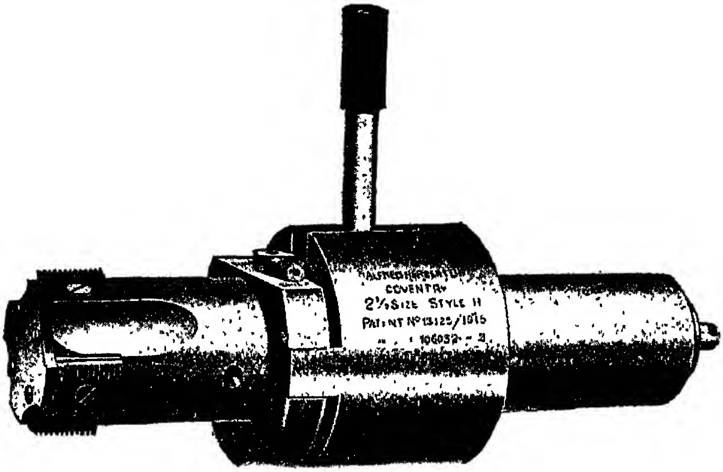


Fig. 14. Coventry Collapsing Tap

(Fig. 14). As in screwing operations, it is best always to bore a recess with the tool shown in Fig. 15, so that the threads of the tap can clear at the end of the blind hole. When solid taps have to be used, a holder similar to that used for solid dies is employed which automatically releases itself when the tap reaches the desired point, the object of both these devices being to avoid the damage that can be done by over-screwing.

A convenient speed for screwing free-cutting mild steel is 30 ft. per min. Harder steels should be considerably slower still. Where solid dies or taps are used the speed of the reverse can be as fast as convenient, as no

actual cutting is going on them. For brass there is no speed limit in the smaller sizes of work, such as that done in bar machines.

Phosphor bronze and other high-tension bronzes require slower speeds for screwing. In bar work there is often more metal to be removed by the tools than in the work done in chucking machines, as in the formation of such articles as bolts, much stock has to be removed, whereas in the machining of castings and forgings there is seldom more than a reasonable amount left for

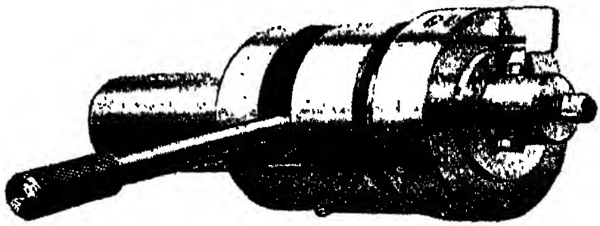


FIG. 15. RECESSING TOOL SHOWING GAUGES FOR DETERMINING DEPTH OF RECESS

machining; it is, therefore, never wise to employ too coarse a feed on tools that are taking a wide chip. The tables of speeds and feeds given here should be strictly adhered to, as, if they are disregarded, short tool life and frequent tool-setting will be the result. We again emphasize the fact that an ample supply of coolant or lubricant at a high pressure is essential for the economical production of good work.

SETTING-UP TOOLS AND STOPS ON A BAR MACHINE

There is no scientific method known whereby the common bar turret can be set up for any particular job; it is a matter of trial and error. The size and class of bar having been selected, a collet of the desired size must be placed in the mandrel and a suitable split collet for feeding the bar put in place. The distance

the bar has to extend from the chuck can then be set by the stop in the turret. A few trials will prove that the feeding collet is properly placed. If a formed tool (see Fig. 10) is to be used, it should be placed in the cross slide, preferably up-side-down, and in the rear tool holder. A few trials will prove that it is set in the right position in relation to the end of the work; afterwards the diameter should be ascertained by trial cuts and the use of the micrometer. When the desired diameter has been produced, the stop governing the movement of the cross slide should be set. The parting-off tool can then be set, and if screwing has to be done the die can be set to screw up to the desired point, and to open in time to prevent damage if there is a shoulder. The heads of such parts as the example shown in Fig. 7 are usually left unmachined.

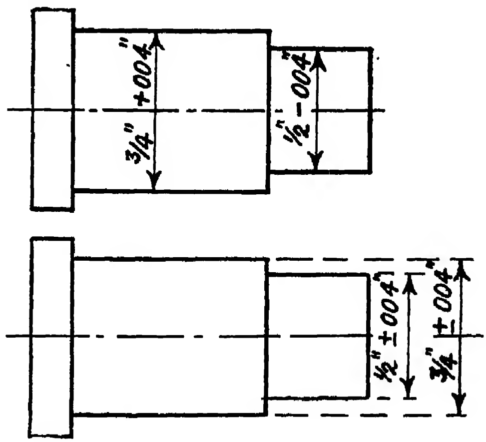


FIG. 16

Above. Example of tool setting which will require resetting after short period.
Below. Sizes specified on drawing

In most work done to-day, there are certain limits of accuracy set down, so the following warning may be useful. Supposing that the limits are as shown in Fig. 16, namely, ·004 + or −, the upper example would comply with this; but such a set-up would be quite useless, for as soon as the slightest inaccuracy should occur, either one or other part would be outside the prescribed limits. In all cases the set-up should have all limits on one side, preferably on the minus side, as tool wear is sure to produce larger work as time goes on.

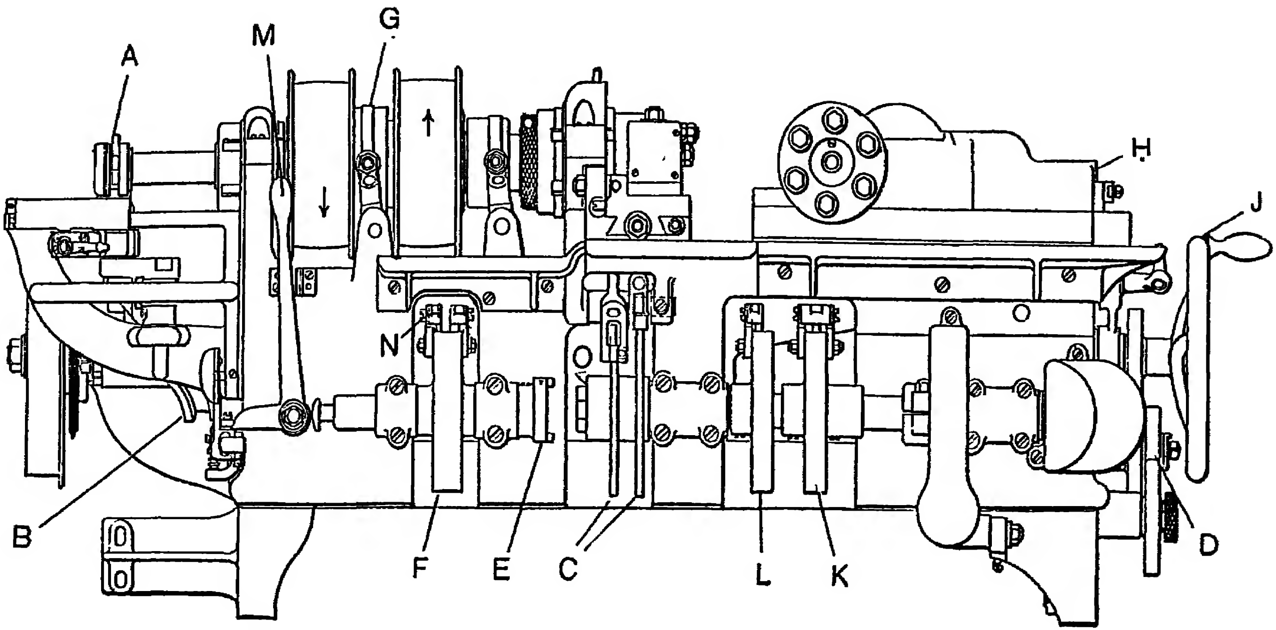


Fig. 17. Front View of Brown & Sharpe's Auto. Lathe

A. Permanent cam which operates the feed of the bar
C. Cams
D. Gears
E. Clutch for operating reversing motion when solid dies are used
N. Dogs for operating reversing motion
K. Disc carrying dogs for indexing turret

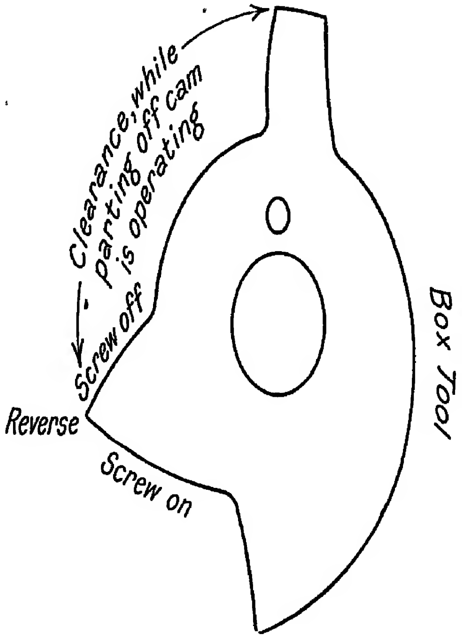


Fig. 18a. Lead-in Turret Cam

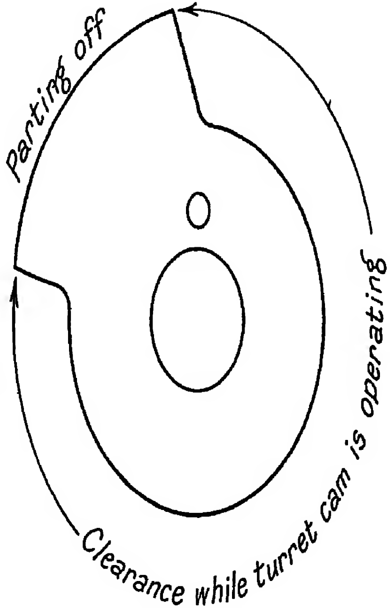


Fig. 18b. Parting-off Cam on Cross-slide

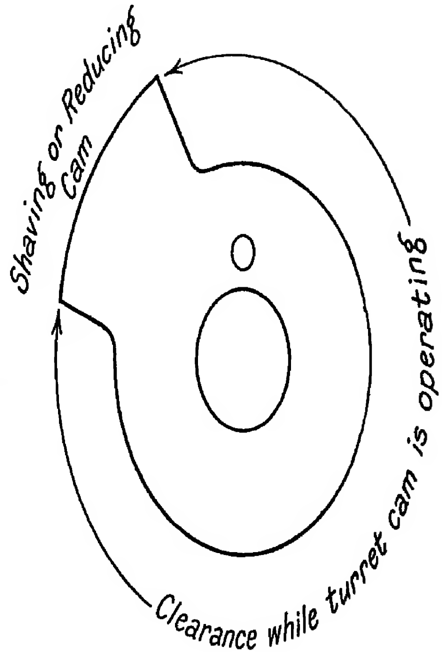


Fig. 18c. Shaving or Reducing Cam in Cross-slide

AUTOMATICS

Multi-spindle automatics are made in which as many as six spindles are at work at once, each one holding a bar and arranged in a circle, the axes of all spindles being parallel with the axis around which the member which holds the tools can revolve. By this means, six operations can be going on at once, each one on a separate bar, so that the time occupied by the longest single operation is the time taken to produce six articles. The setting and management of such machines can only be entrusted to thoroughly experienced workers, so their operation can hardly be dealt with here.

Automatic lathes, like turret lathes, are made in two forms, viz., for bar work, and for chucking, whilst the smaller types are known as automatic screw machines, an example of which may be found in the Browne & Sharp, which is typical of the lighter class of screw machine (Fig. 17).

The Brown & Sharpe Automatic. This machine is made in several sizes, and is usually associated with the production of small articles, screws, etc. Although there are minor differences in the various types, the principle remains the same. For the production of any particular article, a special set of cams is required, one to govern the sliding movement of the slide which carries the turret, which is sometimes known as the lead cam, examples of which are given in Fig. 18, which also shows the cams which govern the movements of the tools in the front and back slides. The setting out of such cams is the work of a draughtsman (who must be thoroughly conversant with the work) and can hardly be dealt with here, for to give a really comprehensive set of instructions which would enable a person not acquainted with the work-to lay out his own cams,

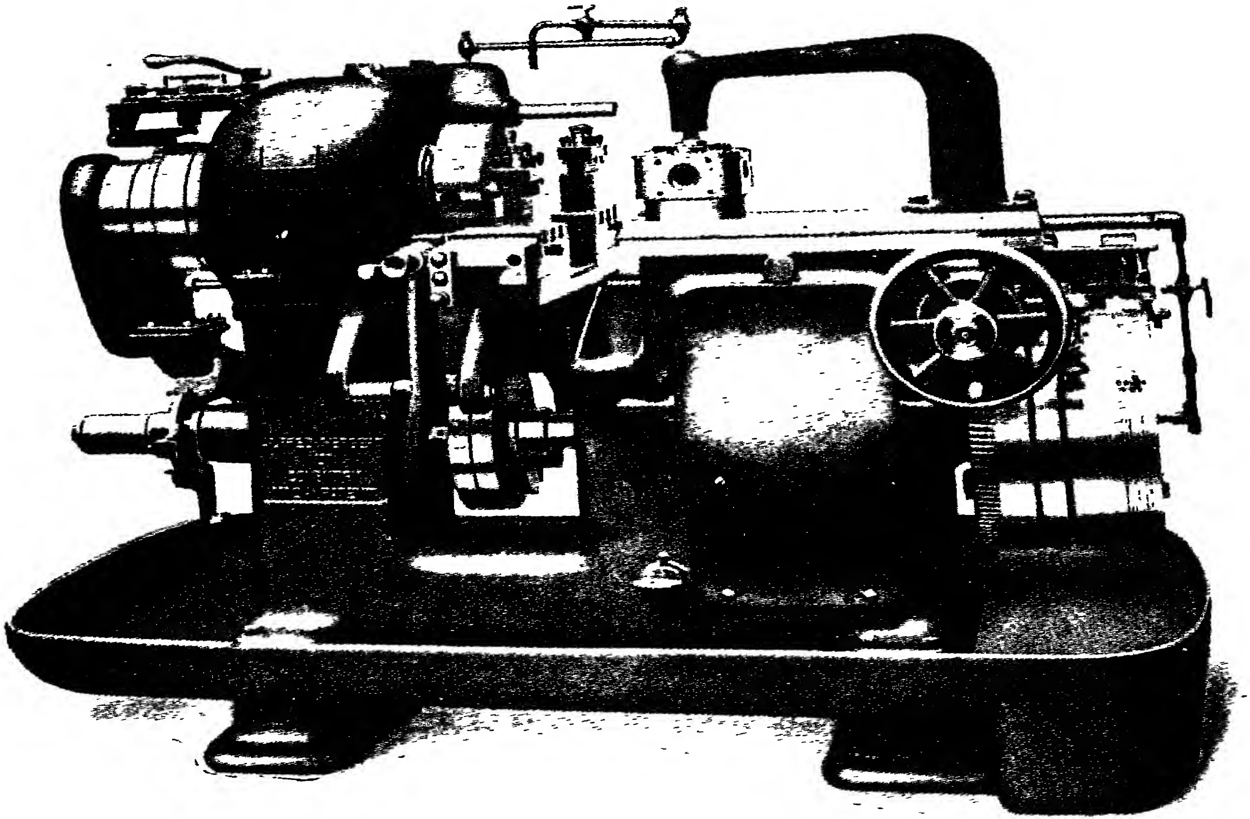


FIG. 19. NO. 2A ALFRED HERBERT AUTO-LATHE

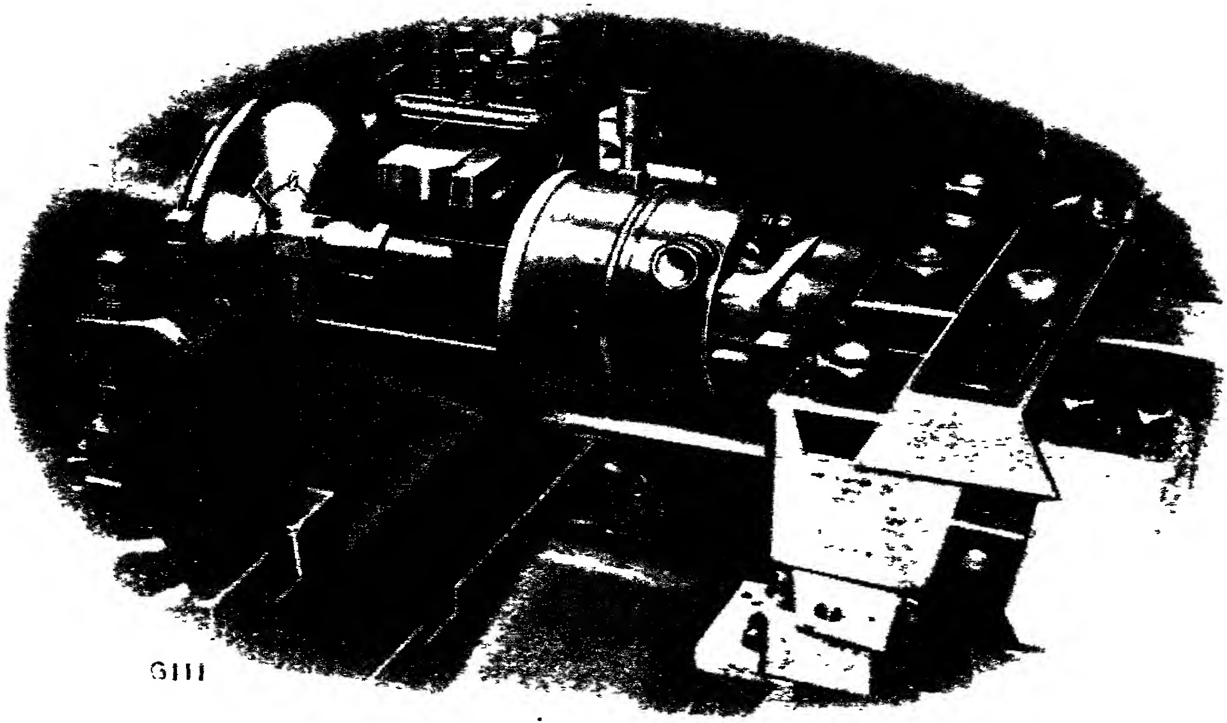


FIG. 20 TURNING AUTOMOBILE AND STEERING BALL (*Alfred Herbert*)

would fill a fairly large book in itself. When such cams are properly designed and made with great care, the most difficult and intricate jobs can be executed to the finest limits.

A typical example of a heavier class of automatic, which is also known as a screw machine, is the No. 2A Alfred Herbert Auto-Lathe (Fig. 19). In this machine, screws, bolts, etc., up to the larger sizes can be produced, whilst in Fig. 20 such a lathe is shown producing a steering ball for motor-cars. In this class of machine no special cams are required, the movements of the turret slide and the cross slide being operated by adjustable stops which govern the speeds of revolution for various operations, also the speeds of feeds.

An example of the heavier type of automatics is shown in the No. 5 Auto-Lathe made by Alfred Herbert, Ltd. (Fig. 21). In this model, heavy chucking operations can be carried out on such parts as steel castings, forgings, etc. Like other Herbert lathes, the movements are all controlled by adjustable stops fixed to the revolving drums, no special cams being necessary.

The number of the various types of automatics is so great that it would be impossible here to give a description of them all; those already mentioned, however, may be taken as the leading types.

As it is not possible to give detailed instructions for the working, setting, and adjusting of all types, we here give a general idea which will be found to apply to most of the known makes.

The large drum usually carries cams or trip dogs which control the opening of the clutch, which, in a bar machine, allows the bar to come forward until it meets the stop arranged to arrest it at the proper distance from the nose. This is the first operation, the second being the gripping of the bar by means of the

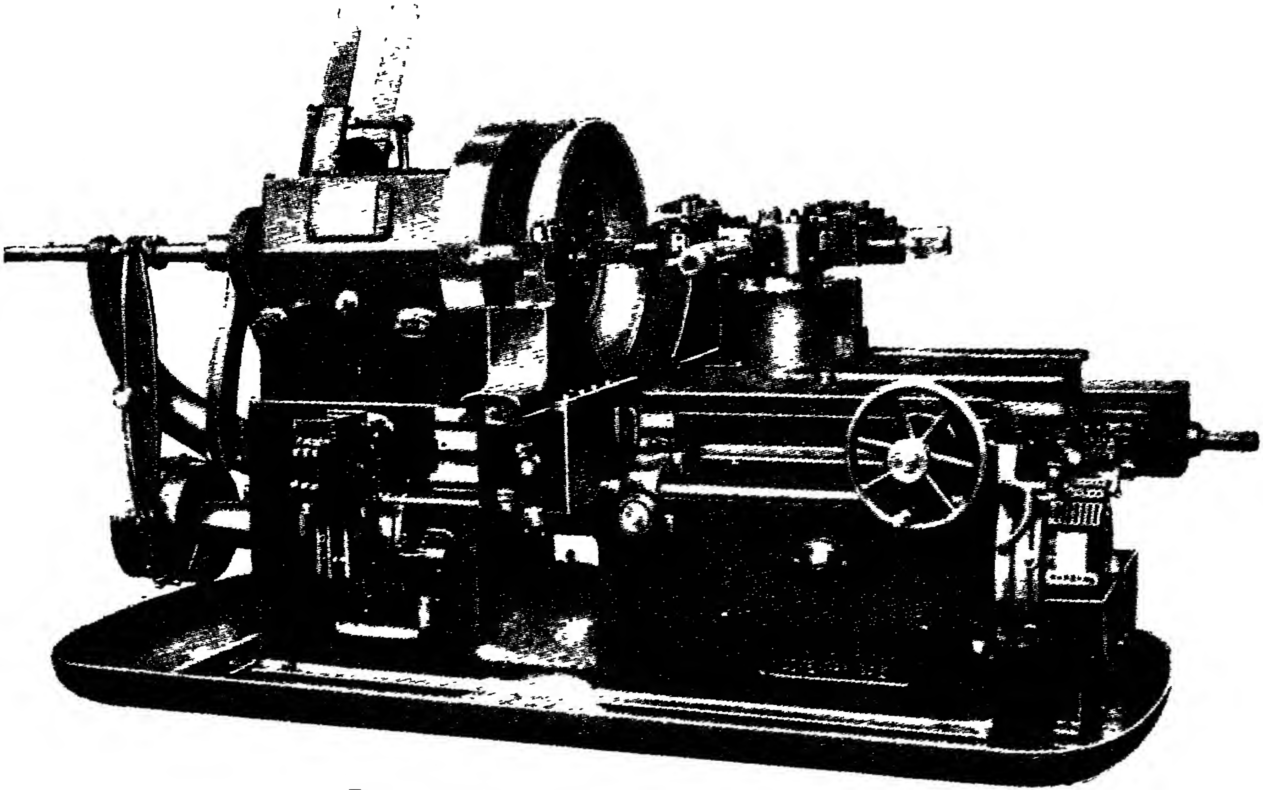
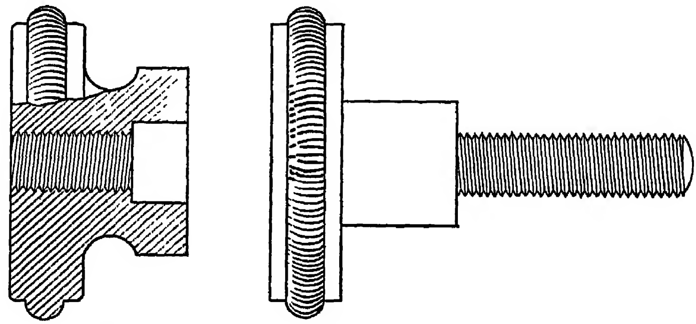


FIG. 21. No. 5 HERBERT AUTO-LATHE

closing of the chuck. The next operation is the receding of the turret slide, so that it can partly revolve without any of the tools fouling the work which is projecting from the nose. This operation of partly revolving the turret is usually done by means of cams. In setting-up, this is usually the first operation; so, having determined the length of the article by means of the stop, the next thing is to set the mechanism that



(A) (B)

FIG. 22. ARTICLES WHERE DUAL OPERATIONS MAY BE PERFORMED SIMULTANEOUSLY

feeds the bar forward. The parting-off tool should then be set so that the article when cut off shall be of the correct length. The various tools for the operations that follow can then be set, but, as work and machines vary so much, no hard and fast rules can be given, the main points to be observed are, however, as follows: One of the main features of the automatic, as well as the turret lathe, is that more than one operation can be in progress at a time, as, for instance, in the article *A*, shown in Fig. 22, where a form tool can be operating on the outside of the article whilst the drilling and counterboring are taking place. In such a case the operations would be—

1. Set stop and feed of bar through spindle.

2. Form completely, whilst forming drill and counterbore.
3. Tap.
4. Knurl.
5. Part-off.

In the example *B* the operations would be as follows—

1. Set stop and feed of bar through spindle.
2. Use box tool with two tools to form stem. At the same time the head can be formed and, in some cases, knurled.
3. Screw.
4. Part-off.

In all work done on an automatic lathe, high spindle or surface speeds and fine feeds generally give the best results, but here again no hard and fast rule can be laid down, but for medium-sized work, when using box tools, a feed of ·002 to ·005 per revolution will be found to give good results, but allowance may be made for the depth of cut, as in deep cuts this may be modified, whilst in shallow cuts it can be exceeded. For forming-tools there may be considerable difference, according to the area which the tool presents to the work, so the larger the area the slower the feed should be. Another factor has to be reckoned with, and that is the stiffness of the work, as if of a slender nature, it is likely to ride in the top of the tool if the feed is too fast. Generally speaking, for medium work the rate of feeding a form tool may be taken as between ·0003 and ·0005 per revolution, whilst for parting-off from ·0007 to ·0015 per revolution will be found correct.

Dummies. Wherever any article is likely to be required again, it is always wise to form one on the end of a piece of short bar, and to mark it with the number of the article and carefully preserve it for a

guide, should more of the article be required at any future time. The use of the dummy is not as an accurate guide for dimensions, but as a rough guide for the tool setter in setting-up again, as by its aid the operation can be greatly simplified. They will be found particularly useful where form tools are employed, and are equally useful for turret lathes as well as for automatics.

Speeds and Feeds. There are few matters where one can find more differences of opinion than in the matter of speeds and feeds, one school relying on heavy feed and slow speed, whilst the opposite school favours fast running with finer feeding. The latter practice is undoubtedly the correct principle, as experience in the use of turrets and automatics has proved. The recent introduction of various metals for tipping tools for turrets and automatics has overthrown all previously conceived ideas of speeds, but not feeds, as such metals as Stellite and others that have followed it appear to give best results when used in conjunction with fine feeds and high speeds.

As these metals used as tips for tools can hardly be considered standard practice, we shall confine our figures to those speeds that are found best with high-grade tungsten steels, which have been hardened in the best-known manner. The list of cutting speeds on pages 1102 and 1103 for turret and auto-lathes is given by permission of Alfred Herbert, Ltd., of Coventry, who are recognized to be the highest authority on the subject in this country. These cutting speeds are intended as a general guide or starting point for the use of turret, capstan, and auto-lathe operators. They are not intended to represent either the maximum or minimum speeds which should be used, and when circumstances allow they may be increased to advantage. On the other hand, where material being turned is not

TABLE I

R.P.M. to Give Various Cutting Speeds with Different Diameters of Work

	Feet per Minute											
	50	60	70	80	90	100	110	120	150	200	250	
Dia. In.	Turns per Minute											Dia. mm.
$\frac{1}{4}$	764	917	1070	1222	1375	1528	1681	1833	2292	3056	3820	6
$\frac{3}{8}$	509	611	713	815	916	1018	1120	1222	1527	2036	2545	9
$\frac{1}{2}$	382	458	535	611	688	764	840	916	1146	1528	1910	12
$\frac{5}{8}$	306	367	428	489	550	611	672	733	918	1224	1530	15
$\frac{3}{4}$	254	306	357	407	458	509	560	611	764	1016	1270	19
$\frac{7}{8}$	218	262	306	349	393	436	480	523	655	876	1090	22
1	191	229	267	306	344	382	420	458	573	764	955	25
$1\frac{1}{8}$	170	204	238	272	305	339	374	407	510	680	850	28
$1\frac{1}{4}$	153	183	214	244	275	305	336	366	450	612	765	31
$1\frac{3}{8}$	139	166	194	222	249	277	305	332	417	556	695	34
$1\frac{1}{2}$	127	153	178	204	229	254	280	305	381	508	635	38
$1\frac{3}{4}$	109	131	153	175	196	218	240	262	327	436	545	44
2	95	114	133	153	172	191	210	229	287	382	475	50
$2\frac{1}{4}$	85	102	119	136	153	170	187	204	255	340	425	57
$2\frac{1}{2}$	76	92	107	122	137	153	168	183	230	306	380	63
$2\frac{3}{4}$	69	83	97	111	125	139	152	166	209	278	345	69
3	64	76	89	102	115	127	140	158	191	254	320	76
$3\frac{1}{4}$	59	70	82	94	106	117	129	141	176	234	295	82
$3\frac{1}{2}$	54	65	76	87	98	109	120	131	164	218	270	88
$3\frac{3}{4}$	51	61	71	81	92	102	112	122	153	205	255	95
	48	57	67	76	86	95	105	114	143	191	240	101
$4\frac{1}{2}$	42	51	59	68	76	85	93	102	127	170	210	114
5	38	46	53	61	69	76	84	92	115	153	190	127
$5\frac{1}{2}$	35	42	49	55	62	69	76	83	104	139	175	139
6	32	38	44	51	57	64	70	76	95·4	127	160	152
7	27	33	38	44	49	54	60	65	82	109	135	177
8	24	29	33	38	43	48	52	57	72	96	120	203
9	21·2	25	30	34	38	42	47	51	64	85	106	228

TABLE I—(*Contd.*)

	Feet per Minute											
	50	60	70	80	90	100	110	120	150	200	250	
Dia. In.	Turns per Minute											Dia. mm.
10	19	23	27	31	34	38	42	46	57	76	95	254
11	17·4	20·8	24	28	31	35	38	41	52	70	87	279
12	15·9	19	22	25	29	32	35	38	47	63	79	304

TABLE II

SPEEDS FOR VARIOUS MATERIALS

Material to be Machined	Speeds in Feet per Minute at Largest Diameter	
	Rough	*Finish*
Mild steel bar[1]	150	*
3 per cent nickel case hardening steel bar[1]	90	*
Mild steel stampings	100	130
3 per cent nickel case hardening steel stampings	60	80
High tensile and cast steel Forgings and bars	45	55
Cast iron	50	70
Steel Castings	50	70
Gun-metal, ordinary	250	250
Gun-metal, Admiralty	120	120
Phosphor bronze	120	120
Copper	250	250
Brass	350	500
Aluminium[2]	500	500

[1] As bar work is generally turned by means of roller steady tools and completed in one cut, finishing speeds are not given.

[2] The limit at which these materials can be cut is usually the highest spindle speed available on the lathe.

uniform in hardness, it may be found necessary to use lower speeds than those given.

Other conditions met in different pieces of work, such as stiffness of the piece itself and the method of chucking, may also affect cutting speeds. The speeds suggested are based on the use of tools of 18 per cent

tungsten high-speed steel, except for brass, copper or ordinary gun-metal, on which carbon steel tools are said to be more durable.

The experience of the writer, however, does not agree with the recommendation that carbon steels will be found more durable when used on brass, copper or ordinary gun-metal, his own experience being that tungsten steel has the same advantage over carbon steel on these metals as it has on steel.

Selection of Bars. A false idea of economy prompts some manufacturers to try and obtain satisfactory results with bars of metal that are not bright drawn, that is to say, what are known as black bars. In the first place such bars cannot be relied upon for accuracy in diameter, with the result that in some cases where they are too large the chucks may fail to close on them, with the result that some part of the mechanism that operates the chuck, being automatic, is strained, and in some cases broken. On the other hand, should the bar be too small for the chuck to hold it securely, the bar may revolve in the chuck. The result of this when a box tool travels along it is that the bar may gradually recede in the chuck, in which case little harm may be done, but when a form tool is brought to bear on the bar by means of the cross slide, the bar may not be sufficiently secured, so it may fail to revolve. The result of this is that serious damage may be done to the machine.

Bars that are not properly straightened should be avoided, as although the operator may do his best to straighten them, the results are never so good as with bars that have been machine straightened. As bright straightened bars are now procurable at a reasonable cost, it is folly to allow an operator to waste time with either black or improperly straightened bars.

The quality of the bars, whether yellow metal or steel,

is of the greatest importance, especially when used in automatics, as some metal, although it may be of good enough quality as regards strength, etc., may not be of a free cutting nature.

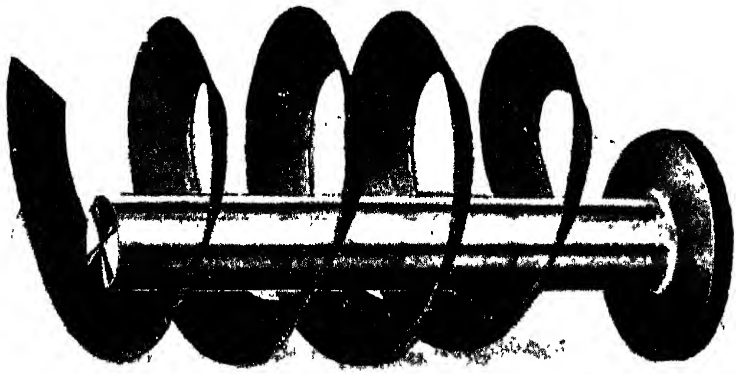
Bars that come from one source of supply should never be mixed with those of another make, as all metals have their own resistance to the operation of cutting tools, so if a machine is set to cut a bar of a certain hardness, and all diameters are found to be correct, a bar of a softer or more free cutting material may cause the tools to produce work that is under size, whilst a bar of harder metal may cause the work to come out over size. The neglect of this precaution has in many cases caused endless trouble to the tool-setter, who may be continually altering his setting if bars of mixed hardness are allowed to follow each other. Although the keeping of bars of one make separate from other makes will in most cases overcome this difficulty, it is found in some cases necessary to grade all bars by subjecting them to the Brinell test and grading them according to their hardness. By this means a great deal of tool-setters' time can be avoided and more accurate work produced.

Lubricants and Coolants. If satisfaction is to be got from the use of automatics, those in charge must dismiss from their minds altogether the idea of the oil-fashioned drip can. Nothing in the nature of dripping lubricant or coolant must be considered if automatics are to give even fairly good results, as the flow must be ample and preferably discharged with some force so that the chips can be carried away. The selection of suitable lubricants and coolants is of great importance, as with a coolant which has but poor lubrication power a broad form tool will give only poor results, so the saving in cost may be lost in the frequent sharpening and resetting of the tools.

Other considerations are the gumming or rusting up of slides that may follow the use of an inferior solution, also the damage that may be done to the hands and arms of the operators through the compound not being antiseptic, as very serious skin eruptions have been known to have resulted from the use of same.

VARIOUS TOOLS FOR USE IN TURRETS AND AUTOMATICS

Perhaps the most important tool for use in both autos and turrets is that which is used for reducing



(Alfred Herbert)

FIG. 23. TOOL FOR BAR REDUCTION

bars by taking off chips in the form shown in Fig. 23, whilst Fig. 24 shows a number of such tools, both right-hand and left-hand. The angle on the top is generally known as top rake, whilst that at the side and end is known as the angle of clearance. The writer has always advocated an acute angle of top rake, as with modern steels, both for tools and for free cutting stock, such angles are possible. Many lathe operators have a fear of having an acute angle of top rake, as they are accustomed to the heavy feeds used in ordinary

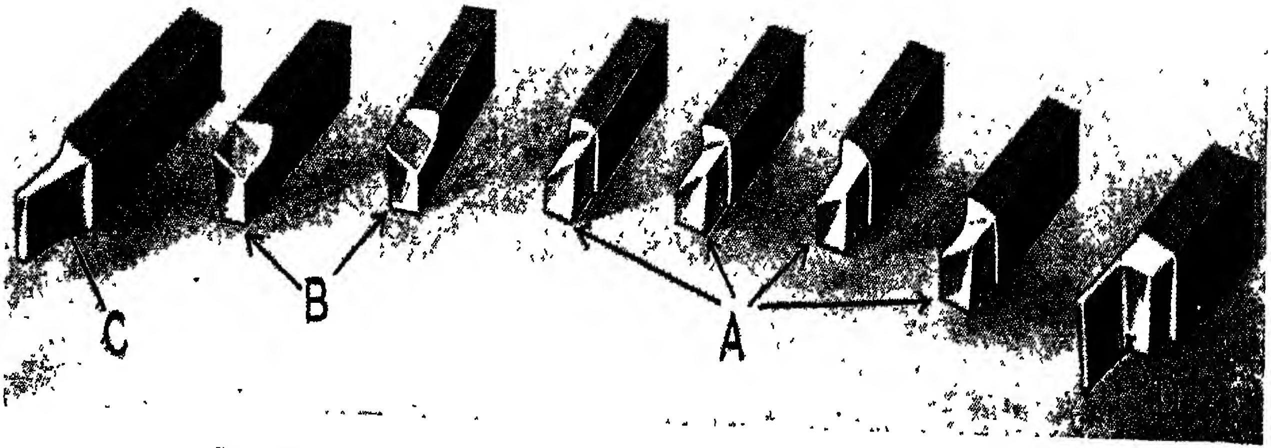


FIG. 24. TURNING TOOLS FOR CAPSTAN AND AUTOMATIC LATHES

The tools shown at *A* and *B* are for use in box roller steady turners. Observe that the top rake is large in all these tools. The tool *D* is a parting or cut-off tool suitable for brass. That at *C* is used for putting on a radius or finishing off a bar

centre lathes, but in turret and auto practice it is found that the angles given in Fig. 25 are quite possible, and are recommended by no less an authority than Alfred Herbert, whose experience in such matters is beyond dispute. Thirty-five degrees top rake and 7 degrees side clearance is what will be found to give the best results, with a front clearance angle of 8 degrees and a radius of $\frac{1}{32}$ in. on the front corner. These angles with a good quality of high-speed steel properly hardened and ground on a wet stone and used with a suitable cutting compound on suitable stock for turning, will be found to answer better than any other form known at present. If success is not achieved, there must be something wrong with one or more of the conditions, so an investigation should be made to find the cause of failure. The above directions apply to tools that are held in a box holder where the work is held in steady relation to the tool, and where it cannot keep rising and falling in relation to the tool. They are also intended for tools that are fed at the speeds recommended.

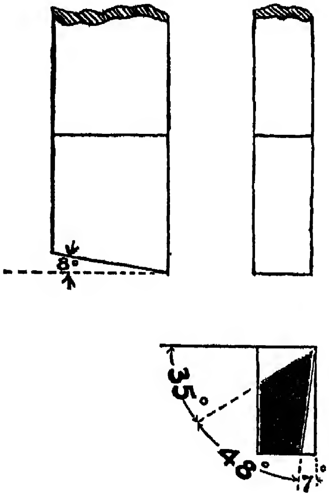


FIG. 25. RIGHT-HAND TURNING TOOL

APPLIANCES USED IN TURRETS AND AUTOMATICS

Chucks for that class of turret or auto which is known as the chucking type, are entirely different to those used for bar work, which have already been fully described. In the opinion of the author there is only one chuck that can be relied upon for such

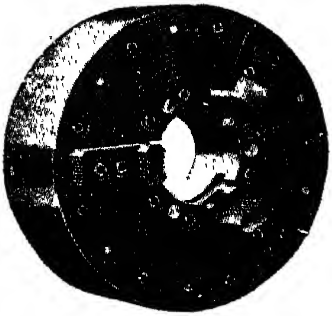


FIG. 26. "COVENTRY" PATENT CONCENTRIC CHUCK

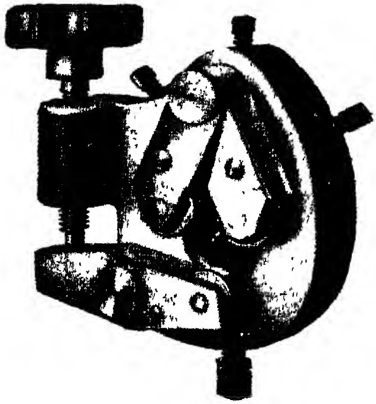


FIG. 27. ROLLER STEADY CENTRING TOOL

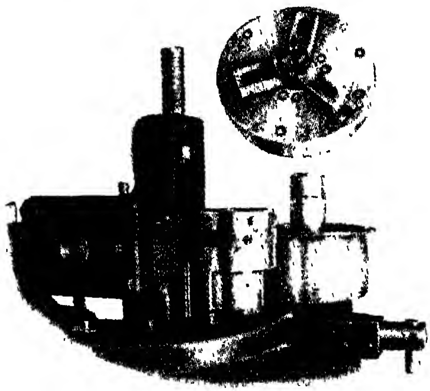


FIG. 28. BACK FACING ATTACHMENT FOR CAPSTAN LATHE

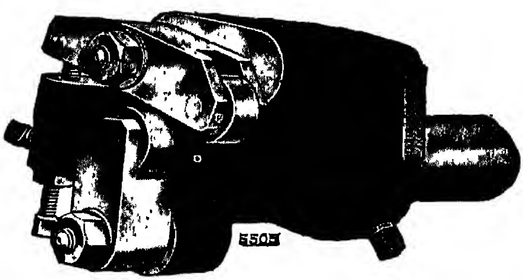


FIG. 29. ROLLER SUPPORT FOR STEADYING WORK

work, and that is the British-made chuck known as the "Coventry," made by Alfred Herbert (Fig. 26). The interior of this chuck has a member which partially revolves by means of a bevelled pinion, thus forcing the three jaws inwards. It differs from the American chucks in that it offers a solid abutment for the jaws instead of the usual scroll. The travel given by this arrangement is very limited, so the jaws have to be removed when different diameters have to be

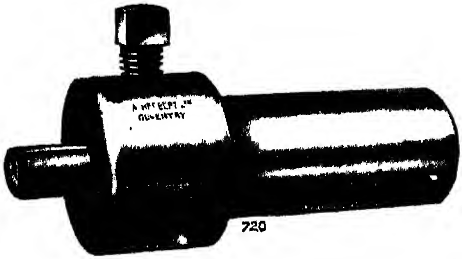


Fig. 30. Adjustable Stop

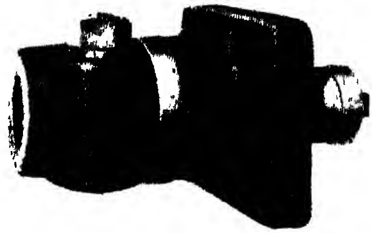


Fig. 31. Floating Reamer Holder

dealt with, and placed on a new set of serrations and bolted up again.

Centring Roller Steady. This appliance is used for centring the ends of work that has been formed in either turret or auto, and has afterwards to be ground or to have some further operation performed upon it (Fig. 27). A centre drill is held in place whilst two rollers are set to approximately the correct distance from the centre, whilst the third roller is adjustable for any slight errors that may occur in the work.

Back Facing Tool. This tool takes the form of an end cutter which can be anchored so that it cannot revolve, and can be fed up to any work that is held in a chuck, so that a part can be faced on the back without taking it out of the chuck, thus saving a second operation (Fig. 28).

FIG. 32. "COVENTRY" ADJUSTABLE REAMER

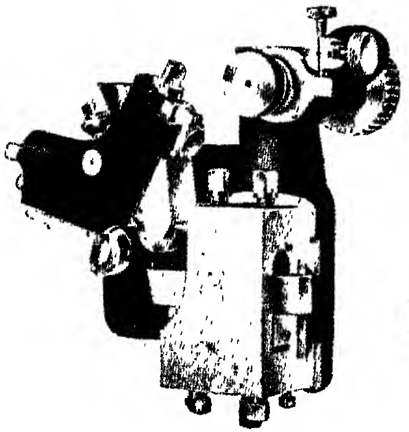


FIG. 33. ROLLER STEADY TURNER FOR BAR WORK

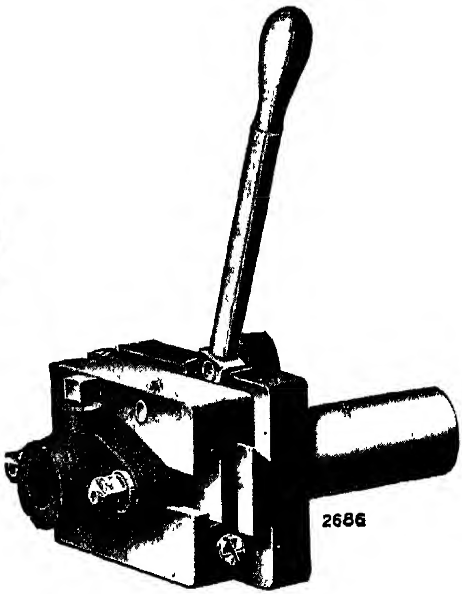


FIG. 34. RECESSING TOOL

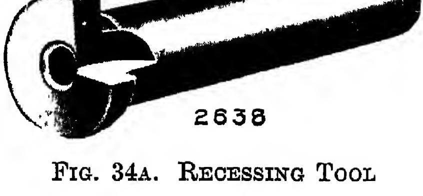


FIG. 34A. RECESSING TOOL

Roller Support. This is used for steadying a piece of work whilst a form tool operates on it. It is generally used for work that extends some distance beyond the nose (Fig. 29).

Adjustable Stop. This is used for determining the length the stock projects from the chuck (Fig. 30).

Floating Reamer Holder. It is well known that unless a reamer can float so as to accommodate itself to any slight error that may exist in any part of a machine, there is a possibility of the hole it produces being bell-mouthed. To prevent this it is usual to allow a reamer to take up its own position when entering a hole, so the floating holder is made for this purpose (Fig. 31).

Adjustable Reamer. As reamers, like all other cutting tools, will wear, it has been found necessary to make such reamers so that they can be expanded, by which means their size may be maintained (Fig. 32).

The Herbert Roller Steady. This steady is especially designed for bar work, and owing to its adaptability for adjustment and its being provided with rollers which reduce friction, it enables work to be produced at a rapid rate, and offers a ready means whereby different diameters can be easily accommodated (Fig. 33).

Recessing Tool. This tool is used for forming a recess at a place remote from the entrance of a hole, which cannot be formed by an ordinary counterborer. It is held in the special holder shown, and is moved from its central position to form the required recess by means of the lever shown in Fig. 34.

In conclusion, the author would like to express his appreciation of the courtesy shown by Alfred Herbert, Ltd., in lending numerous blocks to illustrate this section.

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